PERPUSTAKAAN UTM

UNIVERSITI TEKNOLOGI MALAYSIA

ARTICLES FOR UTM SENATE MEMBERS

"Open Science in Higher Education"

TITLE	SOURCE
Malaysia Open Science Platform	Open Science Forum for Asia & the Pacific (Article from : Malaysia Open Science Platform (MOSP))
Malaysian researchers on open data: The first national survey on awareness, practices and attitudes	Malaysian Journal of Library and Information Science (Article from : Scopus)
Towards the right standards : The intersection of open science, responsible research and innovation, and standards	METODE (Article from : Scopus)
Open peer review: promoting transparency in open science	Scientometrics (Artcle from : Springer Link)

28th APRIL 2021

SOURCE: PERPUSTAKAAN UTM

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UNIVERSITI TEKNOLOGI MALAYSIA

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"Open Science in Higher Education"

TITLE	SOURCE
Gambling researchers' use and views of open science principles and practices: a brief report	International Gambling Studies (Article from : Routledge Taylor & Francis)
Open science for responsible innovation in Australia: understanding the expectations and priorities of scientists and researchers	Journal of Responsible Innovation (Article from : Routledge Taylor & Francis)
Open Science and Its Enemies: Challenges for a Sustainable Science – Society Social Contract	Journal of Open Innovation Technology, Market and Complexity (Article from : MDPI)
Open science practices in higher education: Discussion of survey results from research and teaching staff in Germany	Education For Information (Article from : IOS Press)

28th APRIL 2021

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ARTICLES FOR UTM SENATE MEMBERS

"Open Science in Higher Education"

TITLE	SOURCE
Learning Open Science by doing Open Science. A reflection of a qualitative research project-based seminar	Education For Information (Article from : Web Of Science)
Built to last! Embedding open science principles and practice into European universities	Insights: the UKSG Journal (Article from : Scopus)
Expanding the actions of Open Government in higher education sector: From web transparency to Open Science	PLOS One (Article from : Scopus)

28th APRIL 2021

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PERPUSTAKAAN UTM

UNIVERSITI TEKNOLOGI MALAYSIA

TITLE	SOURCE
Malaysia Open Science Platform	**Open Science Forum for Asia and the Pacific (Article from : Malaysia Open Science Platform (MOSP))**

Malaysian Open Science Platform (MOSP)

open SCIENCE

Malaysia Open Science Platform

Professor Dr Noorsaadah Abdul Rahman FASc

Open science today for new science tomorrow

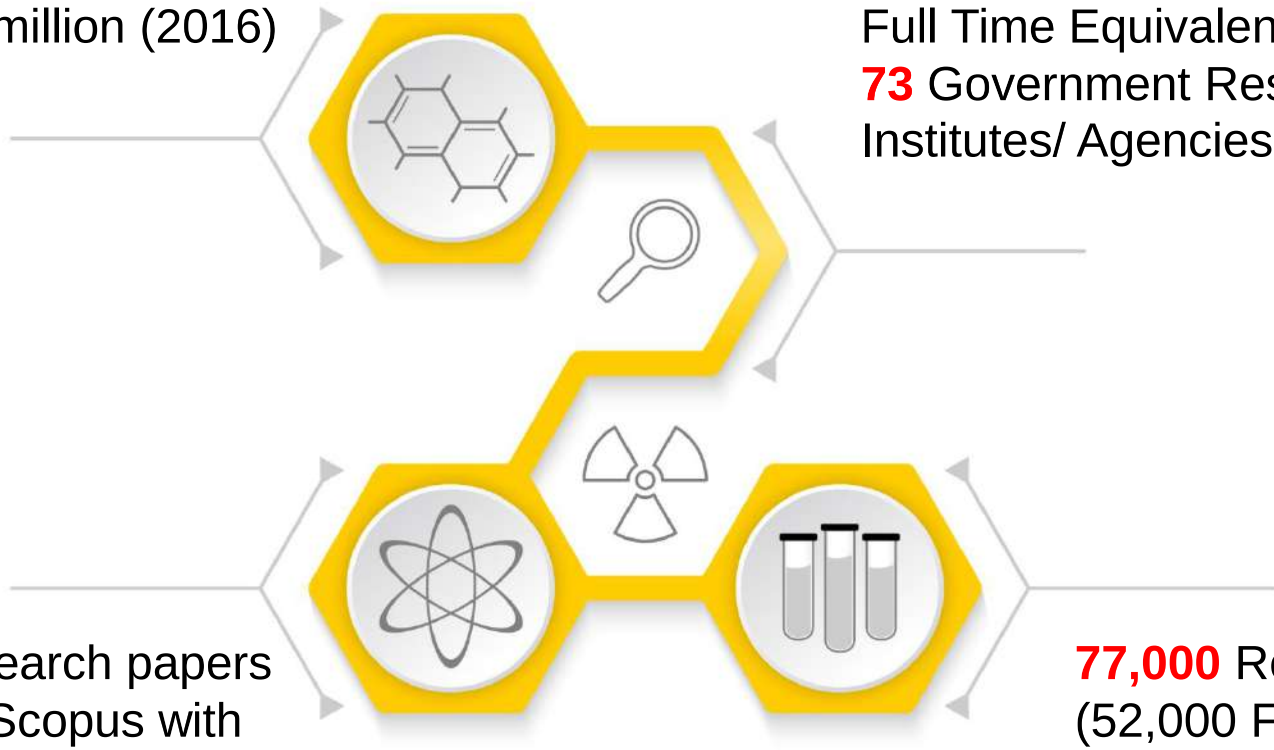
KEMENTERIAN TENAGA, SAINS, TEKNOLOGI, ALAM SEKITAR DAN PERUBAHAN IKLIM

AKADEMI SAINS MALAYSIA

Malaysia Research Landscape

GERD (**1.44%**), RM17,685 million (2016)

12,000 Researchers (5,000 Full Time Equivalent) from **73** Government Research Institutes/ Agencies



230,000 research papers indexed by Scopus with more than 1.7 million citation and more than **100,000** domestic patent filed (2012-2018)

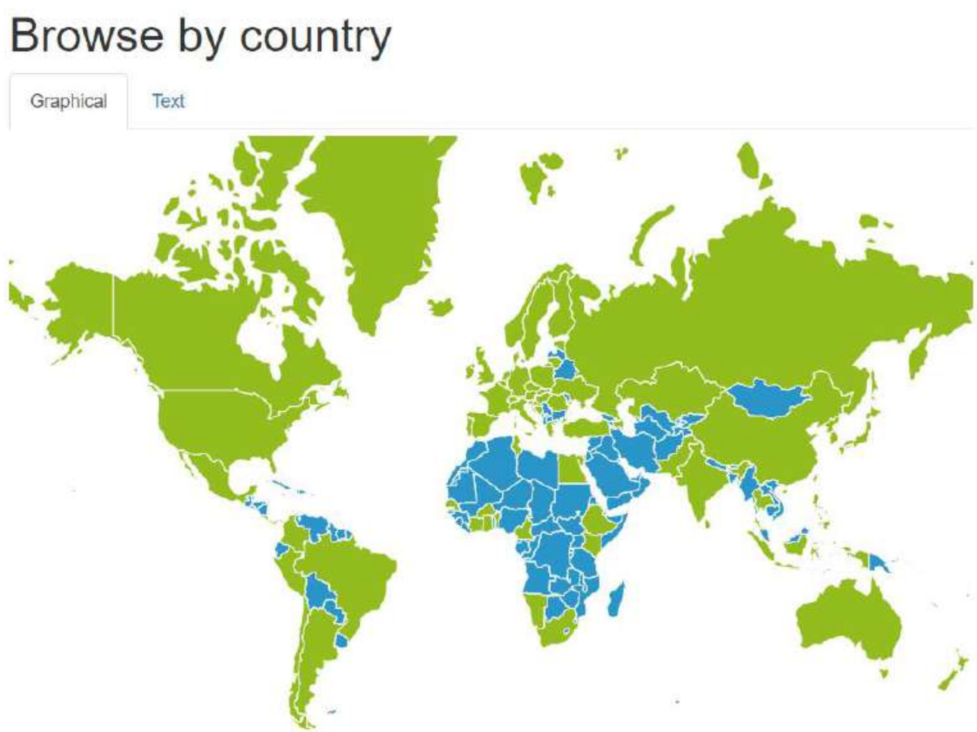
77,000 Researchers (52,000 Full Time Equivalent) from **64** public and private Institutions of Higher Learnings

Source: MASTIC, 2019

Availability of data repositories - 2419

Registered research data repositories worldwide
[(https://www.re3data.org/browse/by-country/)](https://www.re3data.org/browse/by-country/)

- Indonesia (3)
- Phillipines (1)
- Singapore (4)
- Thailand (2)
- No data available for Malaysia



Government Open Data Clusters

New Cluster: Research Data by MOSP

Source: Malaysian Administration Modernisation and Management Planning Unit (MAMPU), 2019

Purpose

To make Malaysia's research data a valuable national asset by developing a trusted platform that enables accessibility and sharing of research data aligned to national priorities and international best practices.

National Alliance on Open Science

1. Malaysian Administrative Modernisation and Management Planning Unit (MAMPU)
2. Ministry of Energy, Science, Technology, Environment and Climate Change – Malaysia Science and Technology Information Center (MASTIC)
3. Ministry of Education (MOE)
4. Malaysia Research University Network (MRUN)
5. Malaysian Research & Education Network (MYREN)
6. Academy of Sciences Malaysia (ASM)
7. University of Malaya (UM)
8. International Science Council Regional Office for Asia and the Pacific (ISC ROAP)

Pilot Initiative

Acknowledgement

Are Malaysian Researchers Ready For Open Science?

Professor Dr Abrizah Abdullah
Faculty of Computer Science and Information Technology
University of Malaya

Malaysian Open Science Research Project

- Seek to determine whether the academia are set to move forward with open initiatives especially when it comes to research and the scholarly communications system, and the best ways to do so.

1. Open science readiness which measures the degree of awareness, practices and perceived benefits accrued to the individual academic researcher, the university, the user of research outputs and to other stakeholders in the open science.
2. Analysis and benchmarking, which appraise Malaysian university's progress in implementing Open Science approaches institutionally, as well as the growth and challenges in universities embracing Open Science principles and values.
3. Open science policy landscape, which identify possible policy actions to strengthen the competitiveness of Malaysian science and research system by enabling it to take full advantage of the opportunities offered by open science

LANDSCAPE SURVEY ON MALAYSIAN RESEARCHERS: AWARENESS, PRACTICES AND PERCEIVED BENEFITS OF OPEN SCIENCE

This questionnaire is sent to you by the Malaysian Open Science Research Project which is seeking to determine whether academic researchers are set to move forward with open initiatives especially when it comes to research and the scholarly communications system, and the best ways to do so. The questionnaire majors on the degree of awareness, practices and perceived benefits which accrue to the individual academic researcher, the university, the user of research outputs and to other stakeholders in the open science.

Open Science aims to increase the transparency of research process and reusability of research output. For the purpose of the survey, please consider the following definitions of some of the main concepts in Open Science.

Open Access(OA): Publishing and dissemination models that ensure the free and open online access to full-text peer- reviewed scientific papers for everyone.

Open data: Data that is made freely and openly available and accessible for reuse, alongside or after the publication of research paper.

This survey will take approximately 15 minutes to complete. You may exit the survey or leave a question unanswered at any time. There is minimal risk attached to your participation. The survey is completely anonymous and individual responses will be kept confidential. Any papers or conference presentations resulted from this research will be based on the aggregated statistics without direct links to an individual survey response.

INFORMED CONSENT
By clicking NEXT and completing the survey, you are indicating that you have agreed to take part in this research and give permission for us to gather and analyze the answers you provide.

NEXT

Page 1 of 6

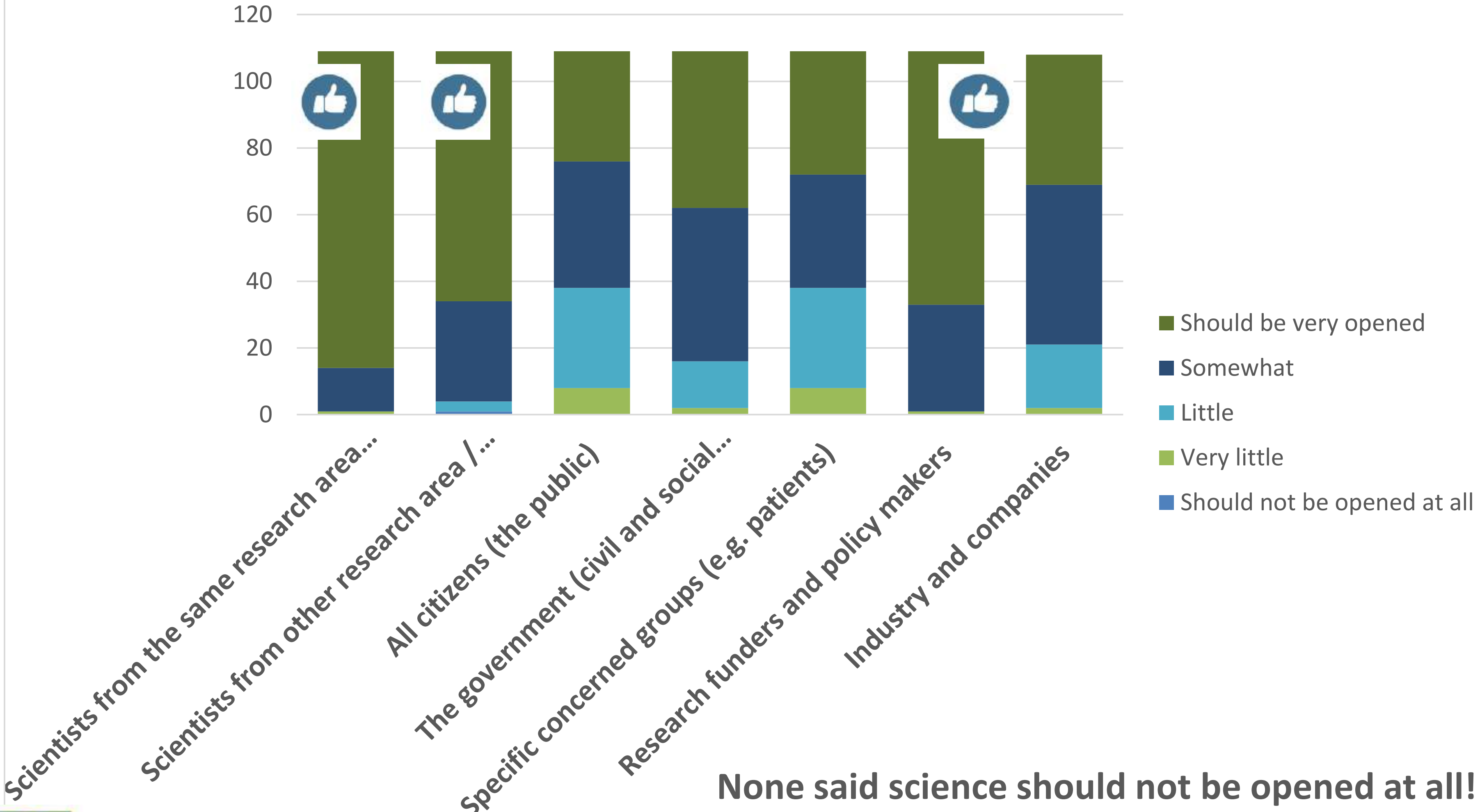
METHOD

Survey of Academics

218

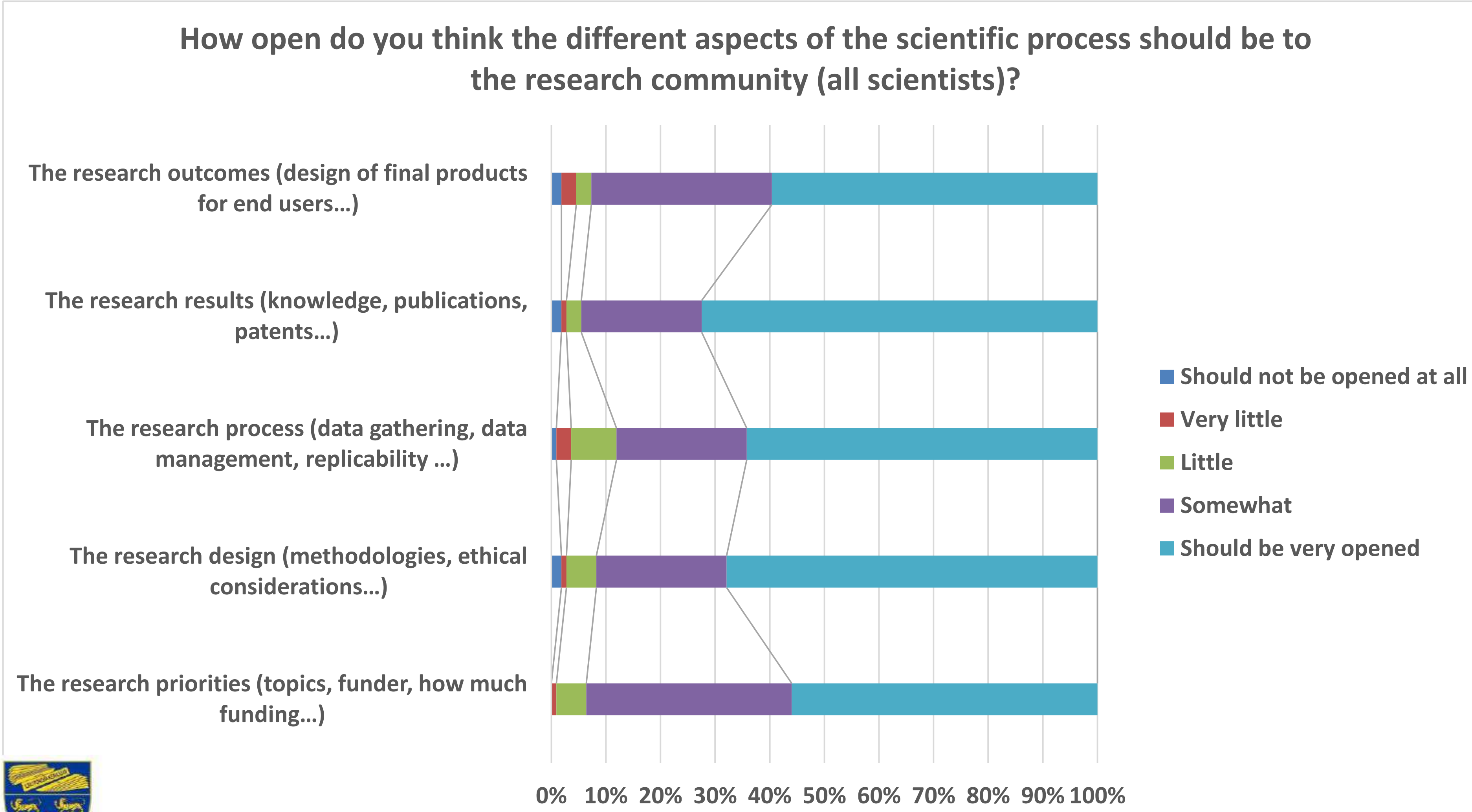
- Research universities (78%)
- Principal investigators (55%); Senior researchers (20.2%)
- Male (51.4%); Female (46.8%)
- Established researchers (40.4%); Mid-career(34.9%)
- Social sciences (31.2%); Life sciences (30.3%);
- Physical sciences (24.7%); Health sciences (9.2%)
- Arts & humanities (4.6%)

ON AWARENESS - To whom should science (research output) be opened?

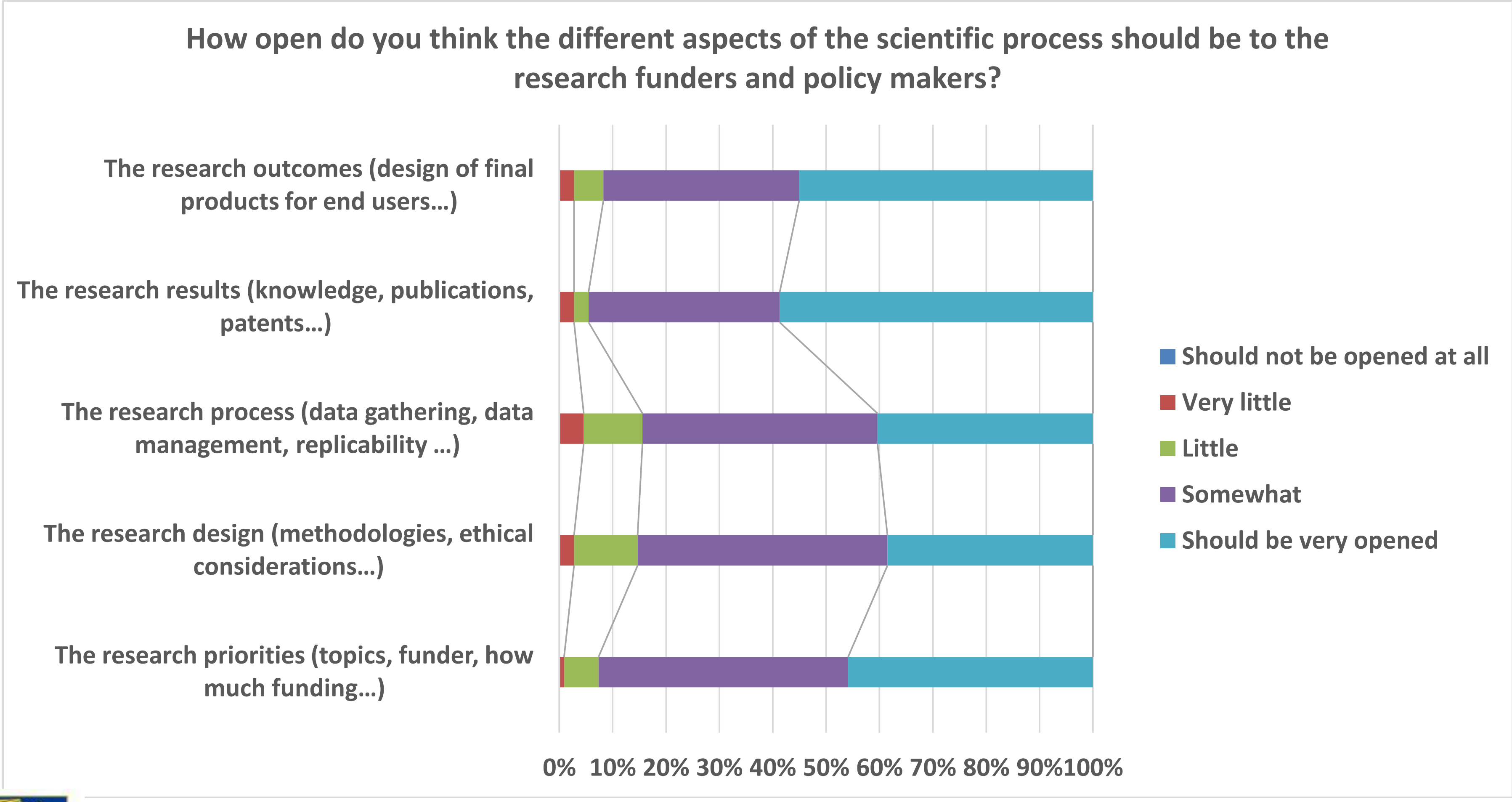


None said science should not be opened at all!

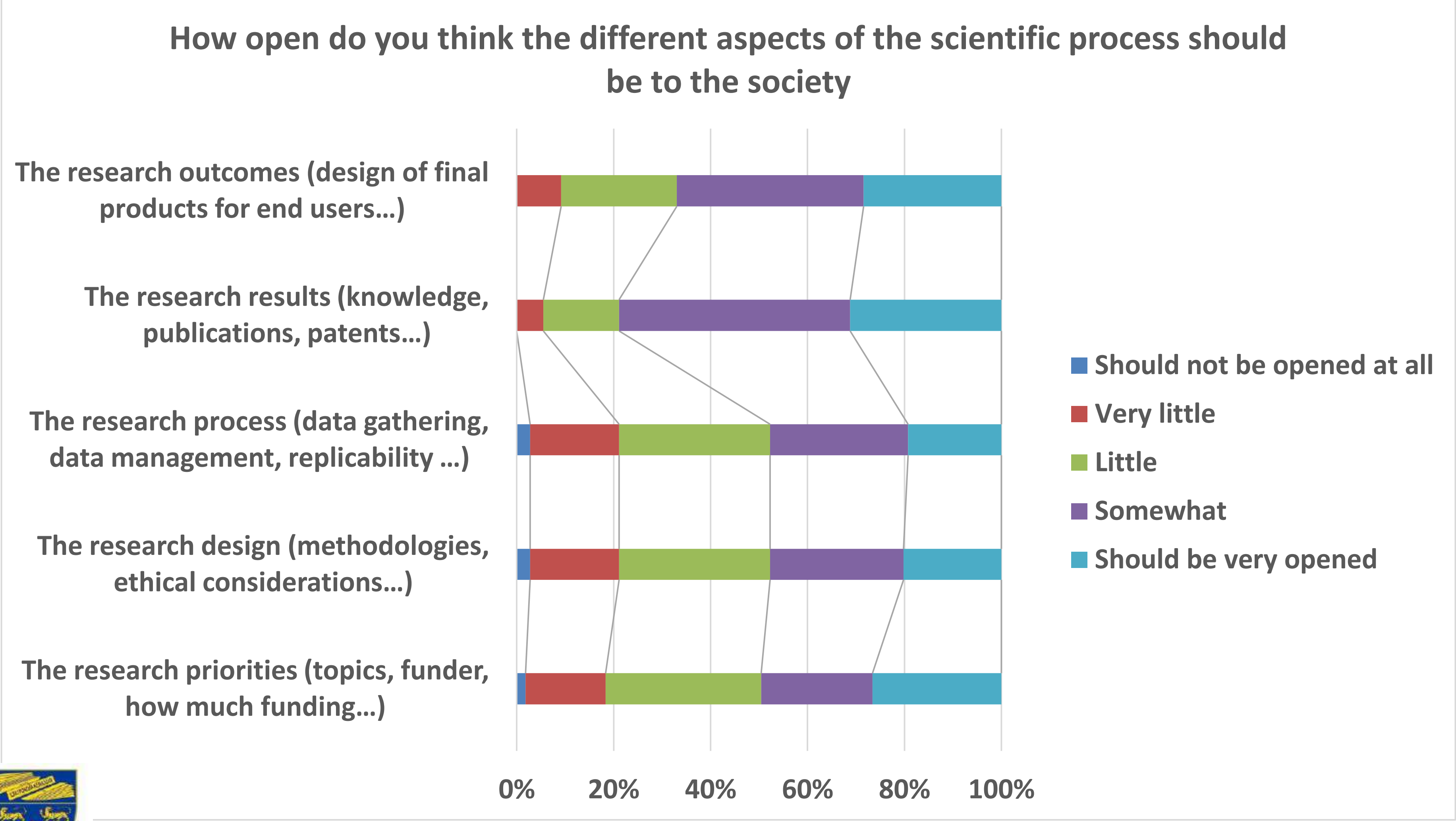
Openness to the research community



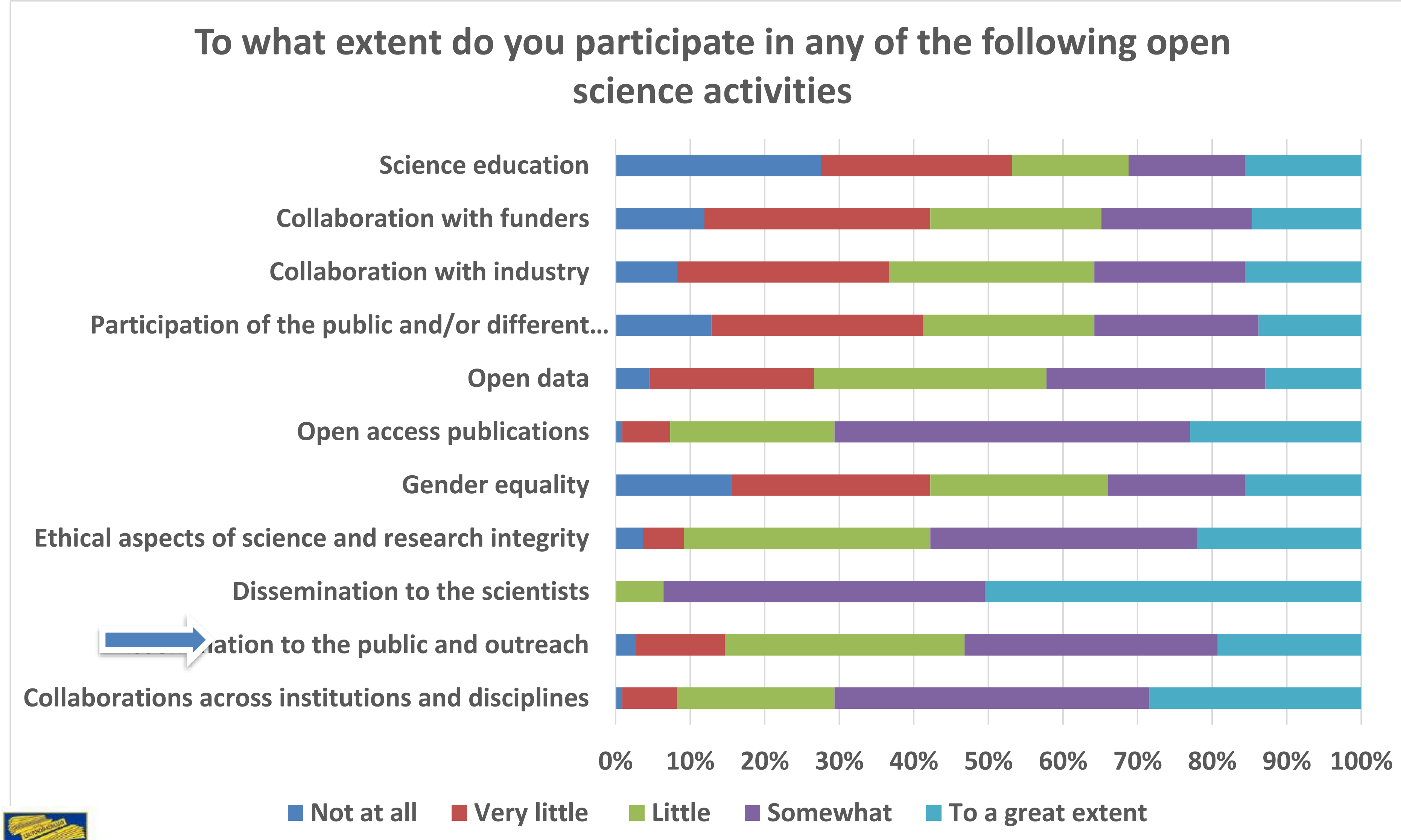
Openness to the research funders and policy makers



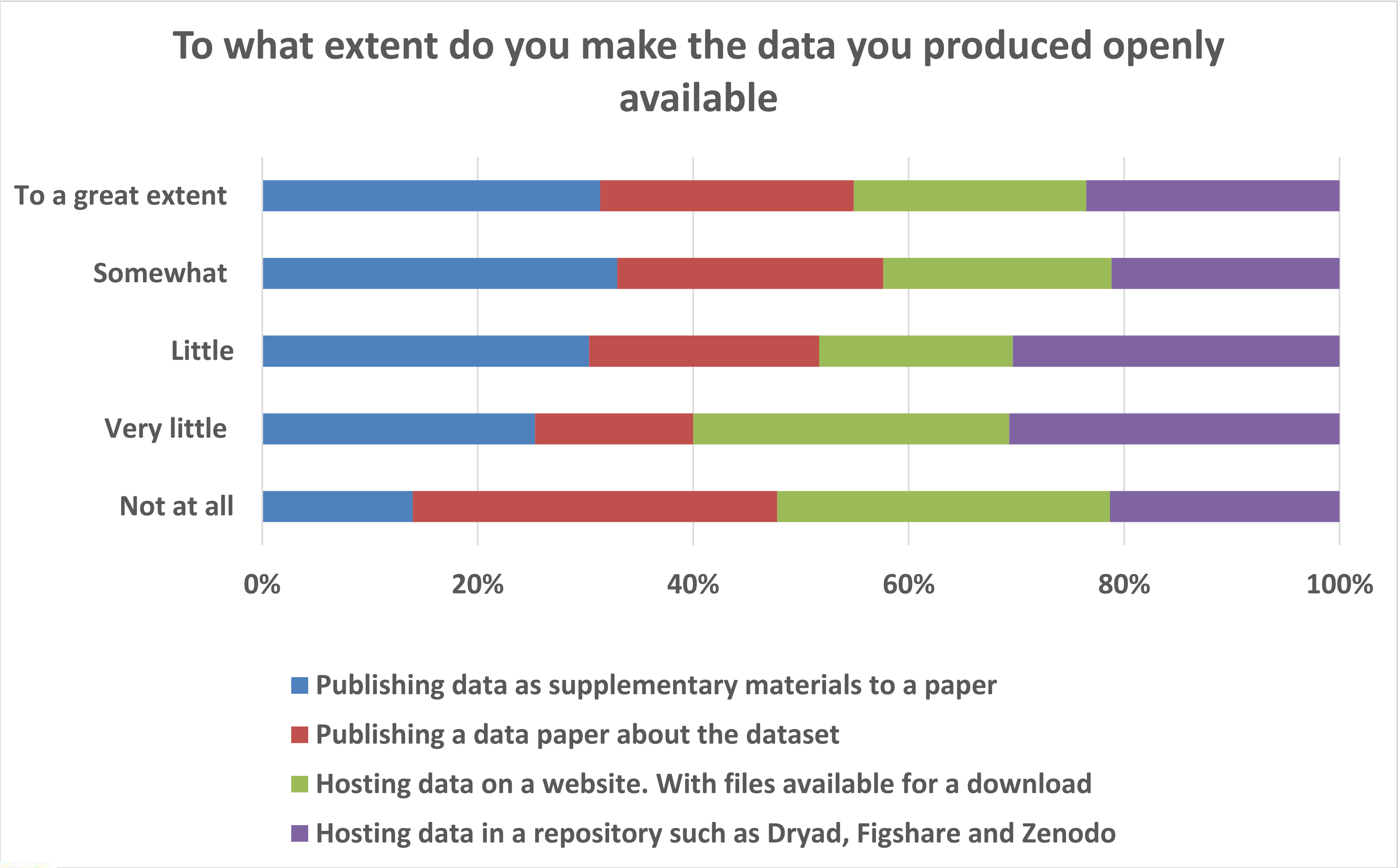
Openness to the society (all citizens)



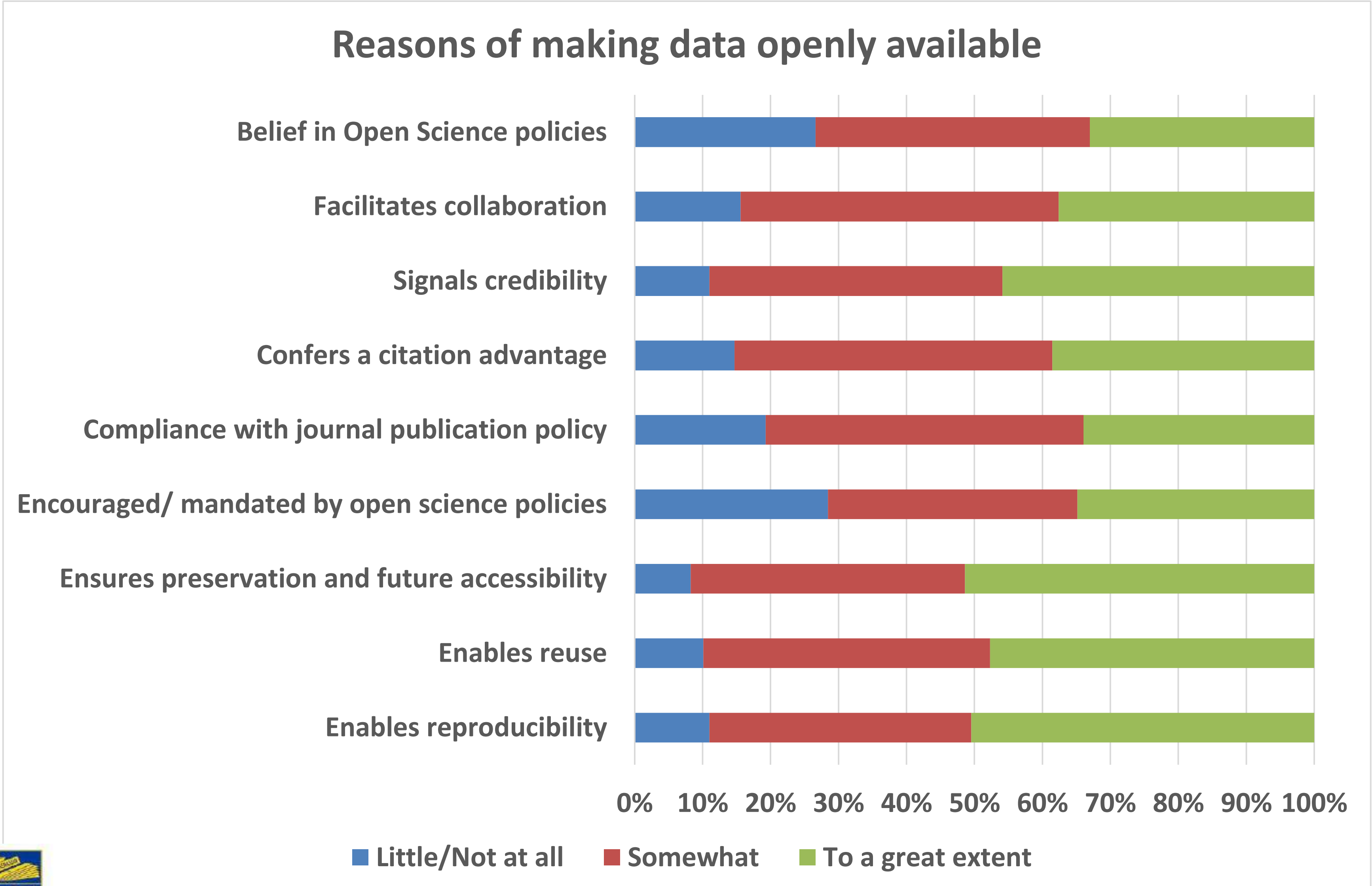
ON OPEN SCIENCE PRACTICES



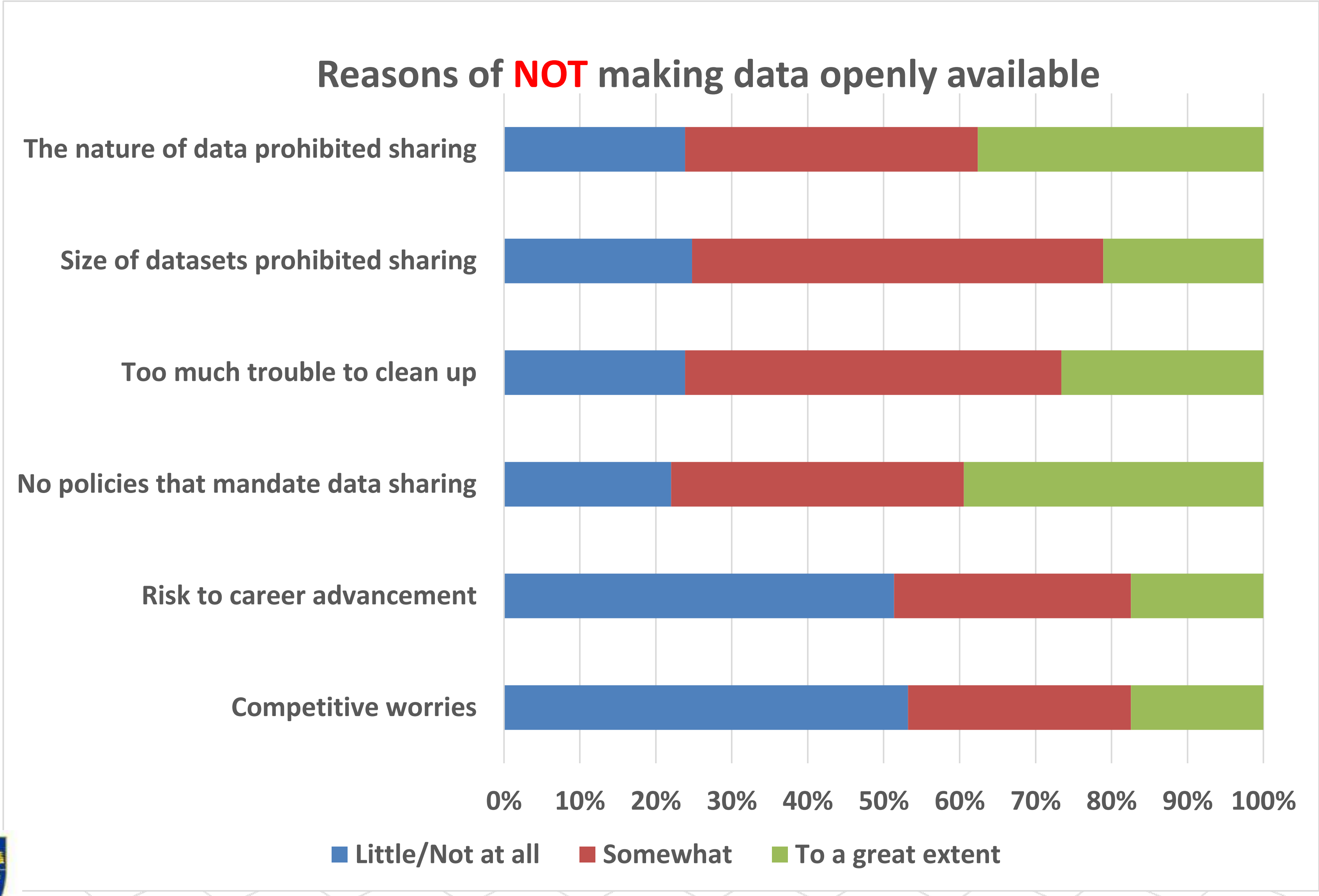
Data sharing practices



Reasons for data sharing

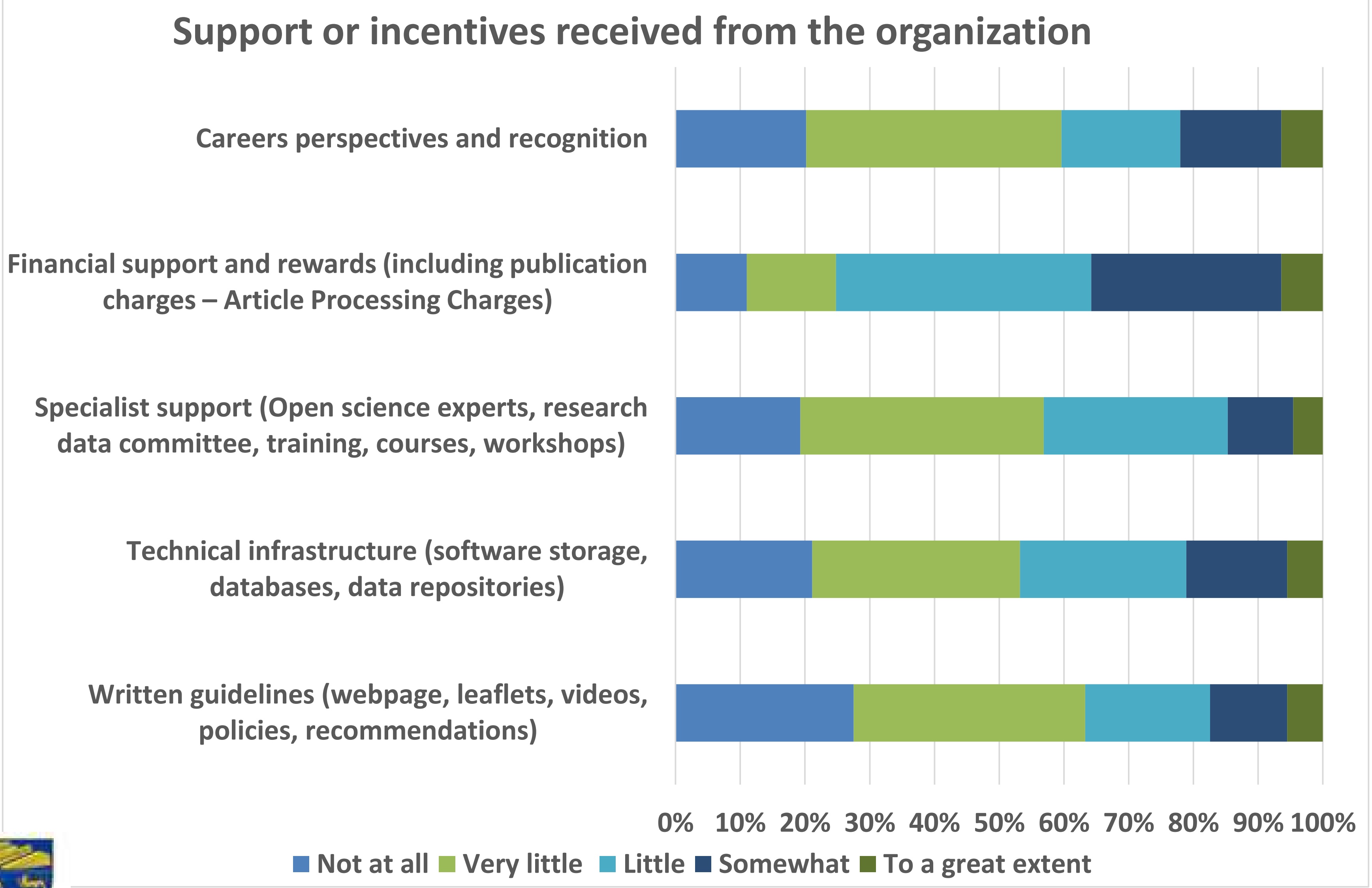


Reasons for data sharing

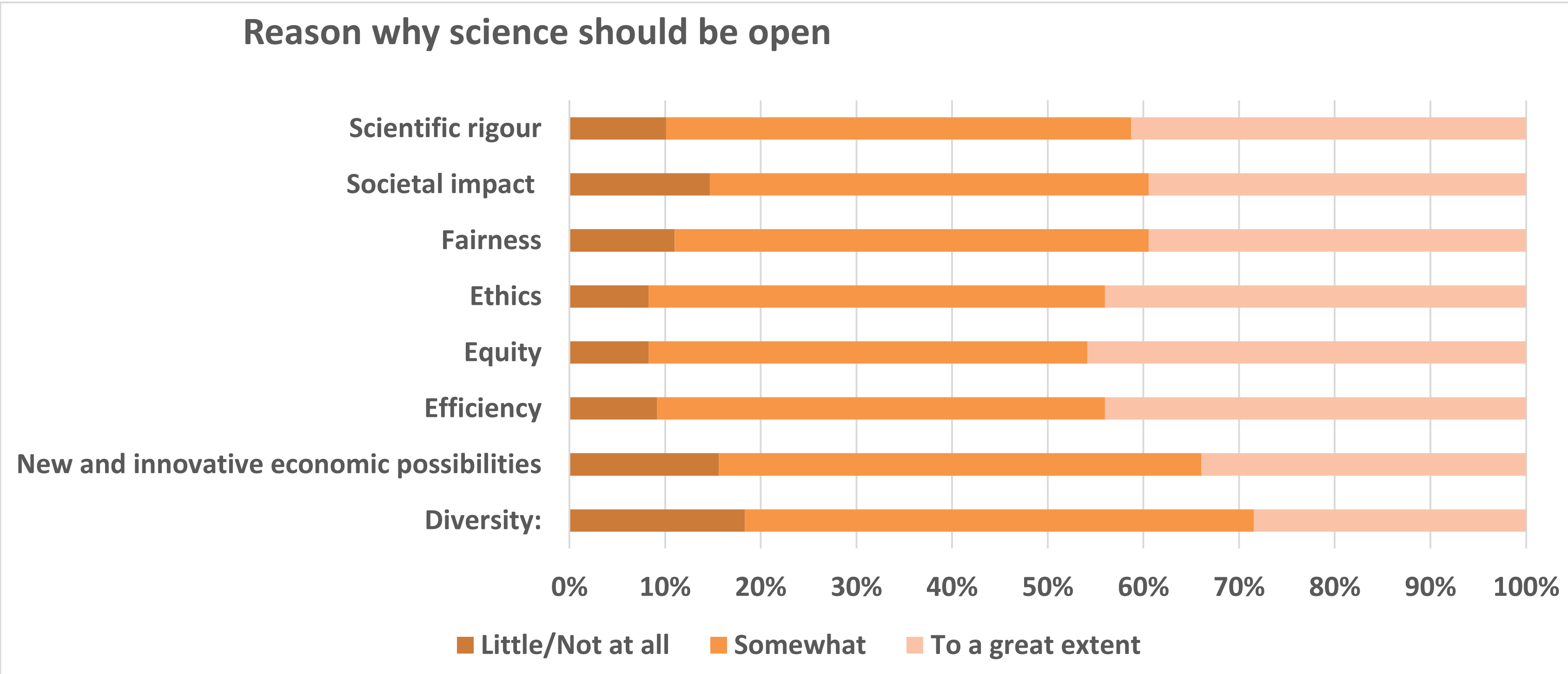


Open Science training received

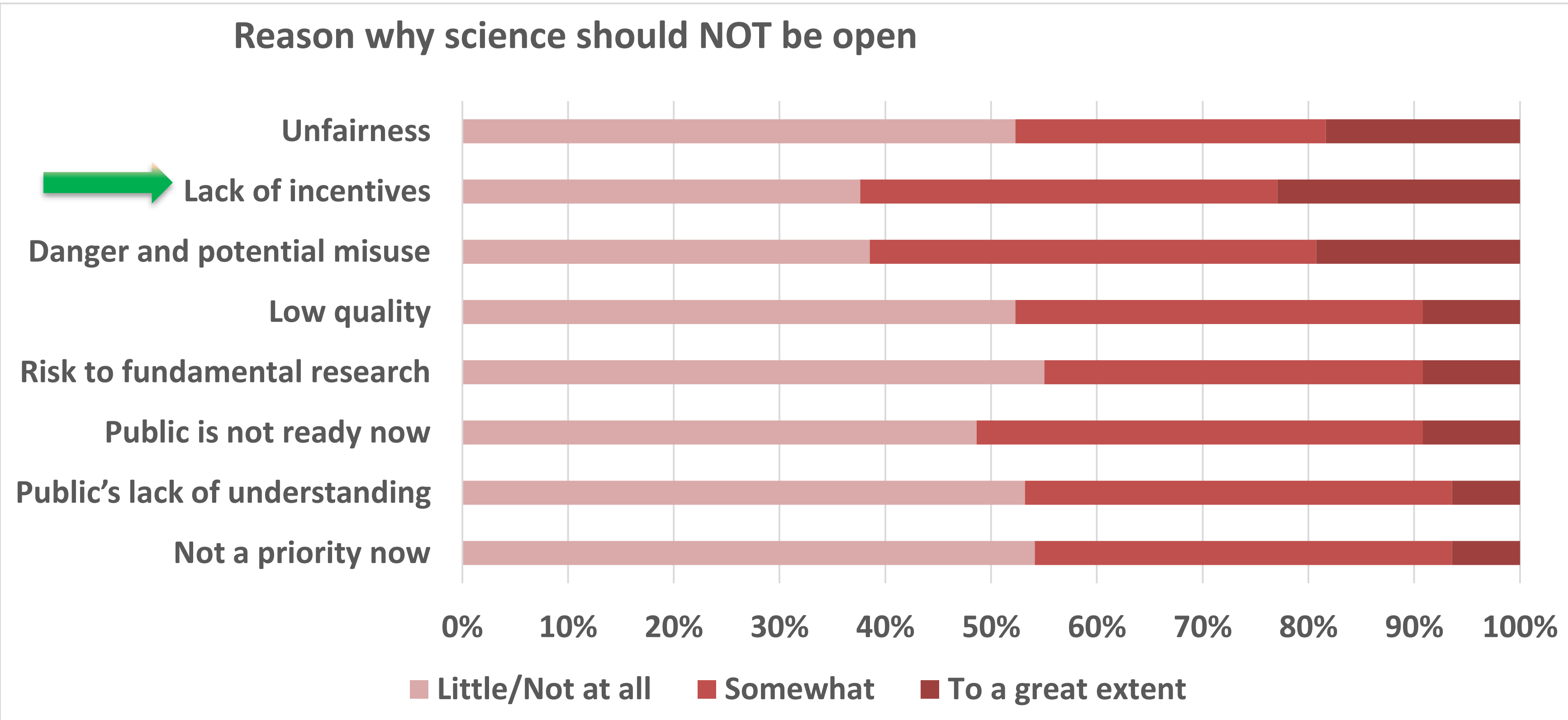
Open Science support or incentives received



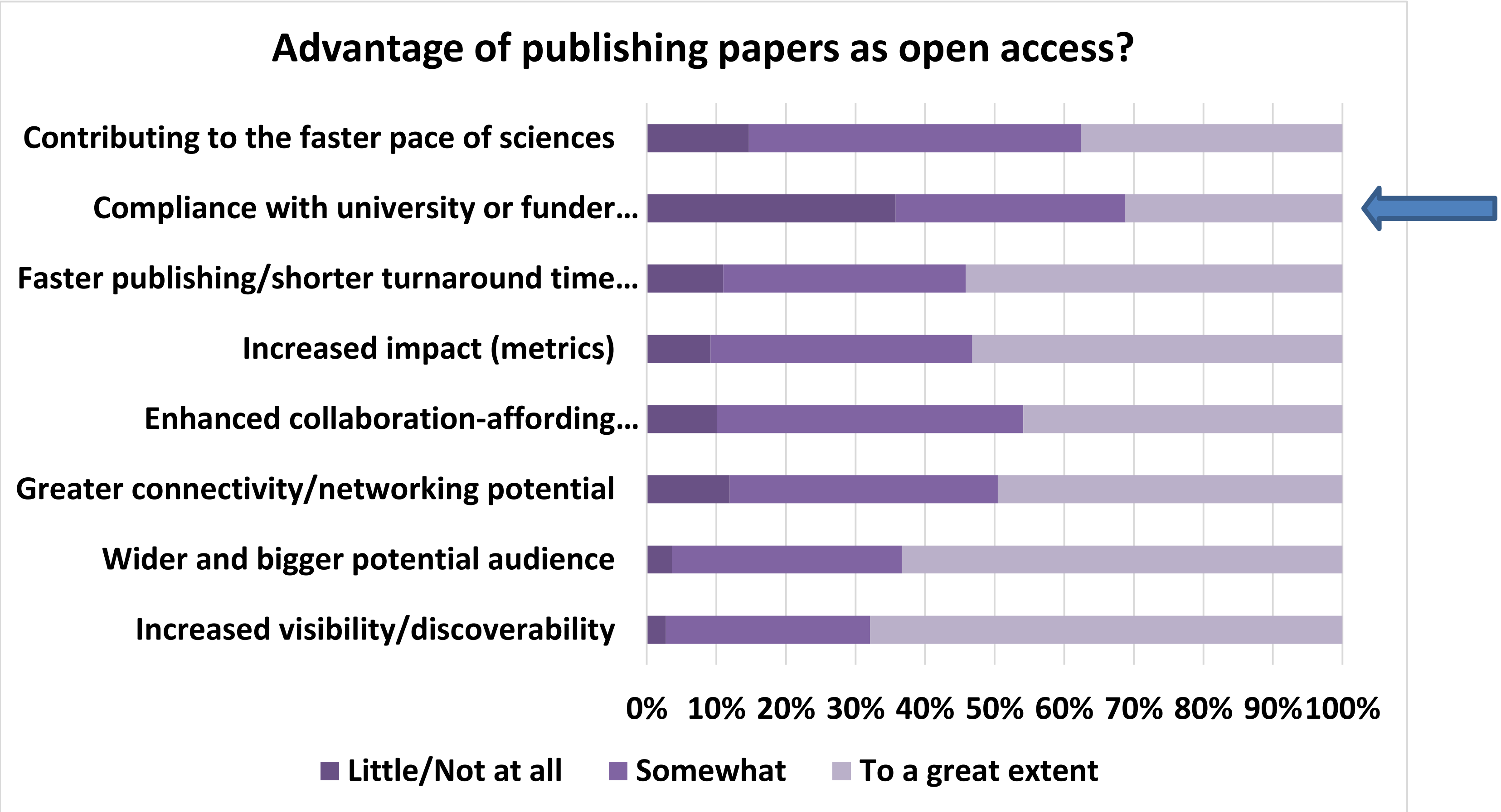
ON PERCEIVED BENEFITS & BARRIERS



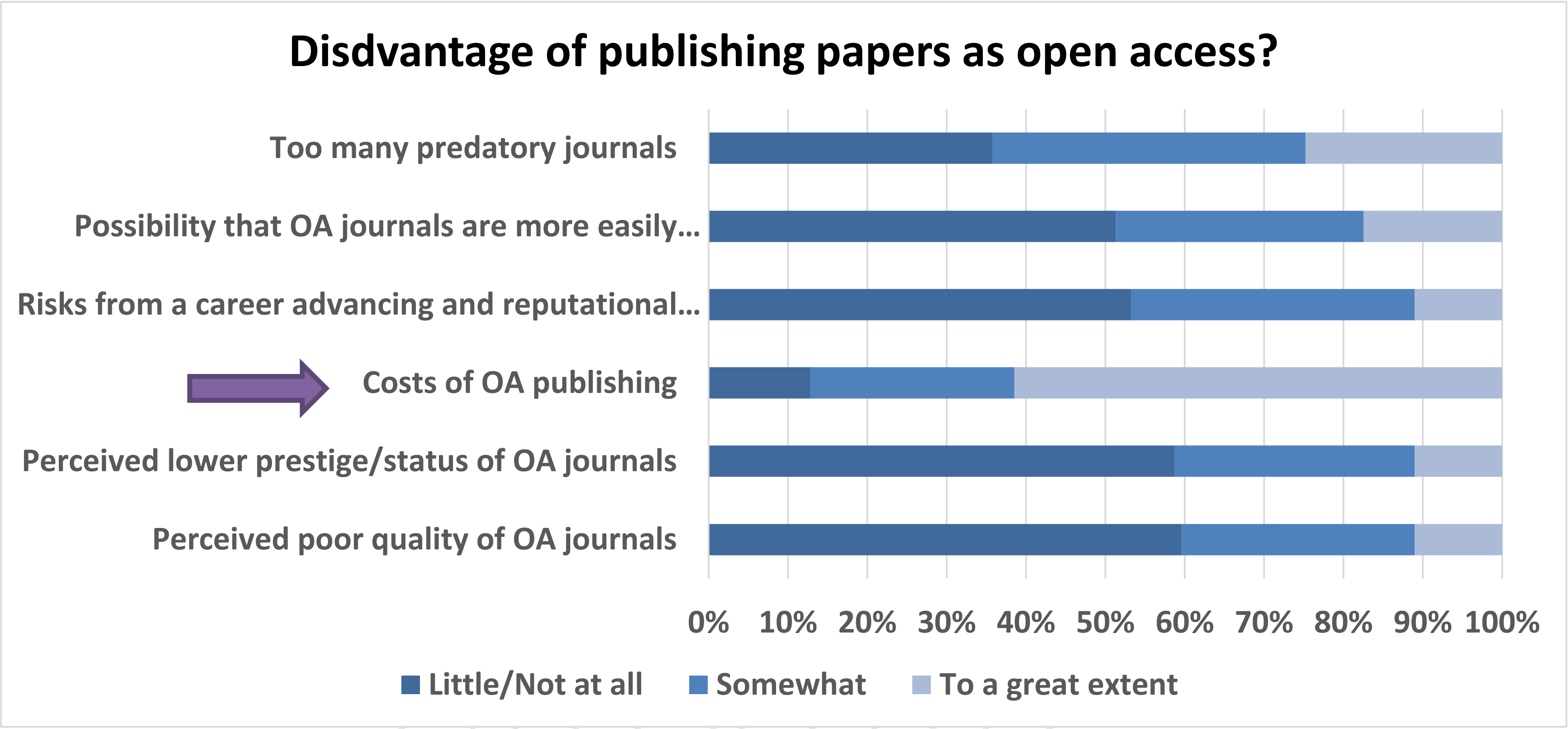
ON PERCEIVED BENEFITS & BARRIERS



ON PERCEIVED BENEFITS & BARRIERS

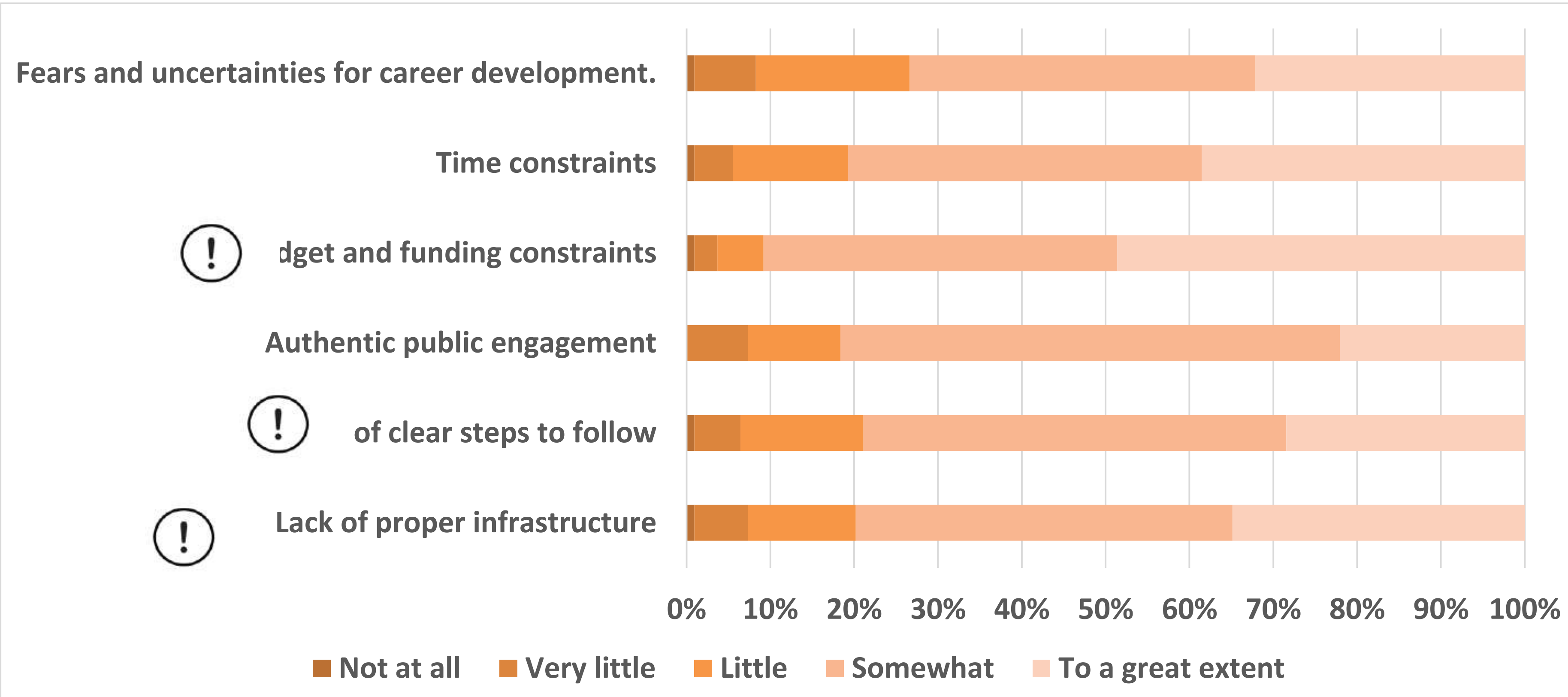


ON PERCEIVED BENEFITS & BARRIERS

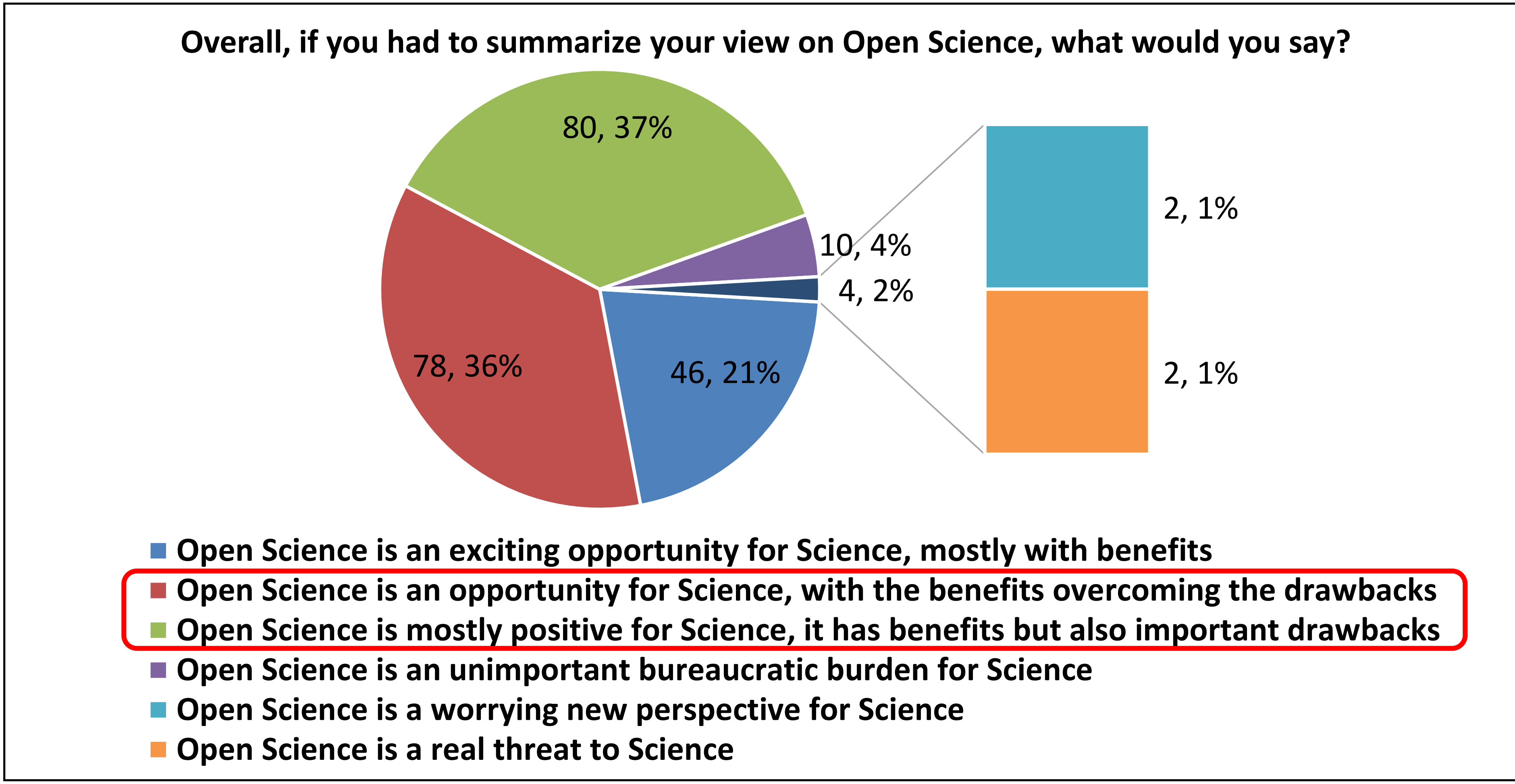


Imagine in your everyday work at your institution you decide to embrace (or you already have embraced) an Open Science perspective.

In your experience, to what extent do you see each of the following as a barrier you will be facing.



Overall view on open science



Highlights of the study

- General awareness - reflect that adoption of open science approaches in universities have been quite limited, confined to openness to the scientific community and funders.
- Practices - confined to open access publishing disseminated to the scientific community;
- Data sharing as a publication requirement; no policies that mandate discourages data sharing
- Open science as positive, but has important drawbacks (esp.fundings)
- Indicates a lack of guidance, training to help researchers learn how to open up their research within a particular domain or research environment
- Implicate that open science readiness and skills are increasingly essential for researchers to undertake responsible research and innovation.

To ensure that researchers are ready and Open Science becomes the norm.......

support a culture change through an outcome oriented training programme

consolidate and sustain training support network from research performing institutions

strengthen the training capacity, address current skills and content gaps on the practical implementation

THIS CALLS FOR UNIVERSITIES TO ....

- Mandate open access science
- Push for open data sharing
- Provide open science technical support and advisory services
- Develop open science infrastructure & roadmap
- Foster and create incentives
- Practise open scholarly communication

Thank you

TITLE	SOURCE
Malaysian researchers on open data: The first national survey on awareness, practices and attitudes	Malaysian Journal of Library and Information Science (Article from : Scopus)

Malaysian Journal of Library & Information Science, Vol. 25, no. 2, August 2020: 1-20

Malaysian researchers on open data: The first national survey on awareness, practices and attitudes

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ABSTRACT

The study investigates the awareness, practices and attitudes of researchers in regard to open data – i.e. the sharing and reuse of research data – which is part of a larger study that concentrated on the scholarly communication readiness of Malaysian researchers in Open Science. The data were gathered by means of a survey which obtained 135 responses from researchers based in five research universities in Malaysia. The main conclusions are: (a) the researchers are aware of open data, yet, they are not practising it as shown in the mean scores, as well as in their responses towards the statements asked; (b) unclear information on data privacy policy, misuse of data, and the fear of losing publication opportunity are part of disincentives for data sharing. The requisite for open data understanding, practices and attitudinal change is needed for these may impact research practices, government policies and scientific knowledge, leading to research transparency and accountability, social benefit and economic growth. This paper concludes with a discussion that policies incentivizing the sharing and reuse of open data, as well as tools and guidance to support data sharing, and a strong incentives and rewards to implement open data among researchers, should be encouraged. Future studies should look into the importance of rewards for data sharing among researchers' institutions. Studies bridging the gap between policy and practices of open data should be examined, if true openness in research is to be established in Malaysia.

Keywords: Open data; Open Science; Research data sharing; Readiness studies; Scholarly communication.

INTRODUCTION

The increased emphasis on managing and sharing data produced in research has propelled many policy makers and international research funders to mandate open data, i.e. making research data openly available with as few restrictions possible in a timely and responsible manner (UK Research and Innovation 2015). The norms and traditions of research reflect the value of openness in the hope to the increase in research efficiency and quality (Piwowar 2011). A major purpose of the drive for open data is openness to availability and access, and reuse and re-distribution, and universal participations (James 2013). Researchers are being asked to make data sharing part of their research workflows, especially by international funders who require the submission of data management plans (Williams, Bagwell and Zozus 2017). Since much data is made available through scholarly publications, publishers also require researchers to make supplemental materials available or publish their data, as it was found that authors were likely to share data if their study

https://doi.org/10.22452/mjlis.vol25no2.1

was published in a journal with a "relatively strong data sharing policy" (Piwowar 2011). Research funders and publishers know that research data can be expensive to produce but inexpensive to share, making reuse more feasible and desirable. Open data, which is a pillar of the Open Science movement, has begun to gain traction worldwide and new government initiatives promoting the deposition of data thrive all over the world every year, often building on the top of transparency and reuse of scholarly data. However, in reality, prior research shows that the data sharing activities especially by scientists in low/middle income countries remains low (Bezuidenhout and Chakauya 2018) and not much is known about open data's use and impacts in developing economies (Verhulst and Young 2017).

Malaysia has recognized the potential of open data in becoming a high-income country by 2020, lifting up the bottom 40 percent of income earners and completing the nation's digital transformation. The Eleventh Malaysia Plan (11MP) specifically identified open data among agencies as critical elements in the move towards more effective, transparent and accountable public service delivery (Malaysia 2015). Malaysia, as a developing scientific nation, has a national focus to continue increasing research output and quality under the Malaysia Education Blueprint 2015-2025; and the nation has achieved an inspiring level of growth within the research sector[1]. Malaysia universities have recently stepped up the open access to their research output, however in many, open data are still restricted, and a concern to speed up the availability of open data through institutional and regulations are in progress. However, with all the benefits associated with opening of data, Malaysian researchers have not yet truly embraced open data. The Open Data Barometer reports that Malaysia lacks the availability of open data for key categories, while on positive side showed that the data actually exist but need to be available for people to use and access the data[2]. Word Bank (World Bank Group 2017) reports on Malaysia's open data readiness assessment (ODRA) based on eight dimensions considered essential for an open data initiative that builds a sustainable open data ecosystem, namely, senior leadership, policy and legal framework, institutional structures in government, government data management policies and procedures, demand for open data, civic engagement and capabilities, funding and open data programme, and national technology and skill infrastructure. The report indicated that the country shows clear evidence of readiness in six of the eight dimensions of the ODRA, which "portends an excellent foundation for realizing the socioeconomic potential of open data" (p.17). Two dimensions which evidence of readiness is less clear are policy/legal framework and government data management policies/procedures (World Bank Group 2017), which may be significant barriers to achieving the vision laid out in the 11MP. World Bank concludes that Malaysia requires a high level of national leadership to achieve agreement on the scope of legislative, regulatory and policy changes that need to be made to turn open data into practice and regular usage for data users (World Bank Group 2017).

To make Malaysia's research data a valuable national asset, the Malaysia Open Science Platform (MOSP) was recently launched as "a trusted platform that enables accessibility and sharing of research data aligned with the national priorities and international best practices"[3]. Although Malaysia's readiness towards open data initiative exists and general supports for the concept is encouraging, but increasing the sharing of open data among

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[1] High growth rate of scholarly output at 7.2% with a 4 times increase in number of citations, 11% yearly growth in number of patents and generated revenues of RM1.25 billion from Malaysia Research Universities as solution providers to industries, agencies and NGOs (Elsevier 2020).

[2] https://opendatabarometer.org/4thedition/regional-snapshot/east-asia-pacific/

[3] https://www.akademisains.gov.my/mosp/about/

Malaysian researchers is a critical issue to be addressed (Abrizah 2019). Researchers opined that data availability is high, but lack of accessibility is a major challenge when it comes to policy and framework (World Bank Group 2017). Malaysia research institutions are data-rich, but not much high-quality research data is released in practices. Notwithstanding, scientific research resolves around the production, analysis, management and re-use of data. Malaysian researchers need to make their research data open for reusability which can also increase accessibility[4]. However, the readiness of Malaysia as a country to meet up with the challenges that may hinder free flow of research data use and re-use is a concern. The motivation for this paper lies in the reasoning that although the availability of open data offers many opportunities for the researchers, no study exists that questions the behaviours and attitudes of Malaysian researchers in open data and the challenges that often arise. The requisite for open data understanding, practices and attitudinal change is needed for these may impact research practices, government policies and scientific knowledge, leading to research transparency and accountability, social benefit and economic growth. To determine whether the academia are set to move forward with open data initiatives especially when it comes to research and the scholarly communications system, this study aims to gauge the awareness, practices and attitudes of Malaysian researchers towards open data. To accomplish this, the following research questions were identified:

(a) To what extent are the Malaysian academic researchers aware of open data?
(b) To what extent have they personally experienced open data sharing?
(c) What are the disincentives to open data sharing among Malaysian researchers?
(d) What are the Malaysian researchers' attitudes towards open data?

LITERATURE REVIEW

In the context of this study, open data, refers to online, free of cost, accessible data that can be used, reused, and distributed provided that the data source is attributed and shared alike (FOSTER (Facilitating Open Science Training for European Research) 2017a). Open data is a component of Open Science, which is described by FOSTER (2017b) as "the various movements that aiming to remove the barriers for sharing any kind of output, resources, methods or tools, at any stage of the research process". At the core of the library and information science field, the focus of Open Science is placed on two of these movements: open research data and open access to scientific publications. Much has been studied on the general movement that result in open access, however very few studies have looked at the extent to which open data is understood, practiced and perceived.

Much of the literature on open data touch on the issues of open data sharing. Data sharing increase the credibility of research findings, providing evidence to support analytic frameworks and decisions and a source for a researcher to consult when building on existing studies (National Research Council 1985). Tenopir et al. (2011) emphasized the importance to study the data sharing practices of researchers as it is a valuable part of the scientific method allowing for verification of results and extending research from prior results. Researchers can have diverse motivations to share their data, and to re-use research data already available, and most of the time sharing research data sets is mostly driven by personal decision (Savage and Vickers 2009). Studies show that there is great variation among research fields in their data-sharing norms (Curty et al. 2017; Fecher,

[4] Vice Chancellor of the University of Malaya in 2018, Datuk Ir. (Dr.) Abdul Rahim HJ. Hashim, at the 6th Global higher education forum on "thriving for knowledge, industry and humanity in a dynamic higher education ecosystem"

Friesike and Hebing 2015; Zuiderwijk and Spiers 2019), to such an extent that different fields can be said to have different data cultures (National Research Council 2009). For example, data availability is high in disciplines that have well-developed traditions of open access and less so in disciplines where data sharing is uncommon. Tenopir et al. (2011) who investigated 1,329 scientists' data needs, sharing practices and intentions, found out that that social science researchers are less likely to make their data electronically available to others when compared with their science counterparts.

Combining information from a bibliometric analysis, a survey and case studies (carried out in Netherlands), CWTS and Elsevier examined how 1,162 researchers from various disciplines worldwide share data, the attitudes of researchers toward sharing data, and why researchers might be reticent to share data (Wouters and Haak 2017). The key findings were that attitudes are generally positive, but open data is not yet a reality for most researchers. Data sharing principles is dependent on the field and practices in that field: for example, researchers in intensive data-sharing fields are advanced in data curation, storage, and sharing, whereas researchers in restricted data-sharing fields are more traditional in terms of knowledge production and dissemination. They are aware of data repositories, but they keep data to themselves and share it through publication or collaboration, making it less accessible or open.

There has been good evidence for a culture of devalued sharing concerns data publishing. Sayogo and Pardo (2013) outlined specific reasons from four perspectives: technology, organizational, legal and policy, and data complexity due to local context and specificity. Although open data sharing policies as well as the technology to facilitate data sharing are quite increasing (Crosas 2012; Crosas et al. 2015), scholars do not share their data even when ethically required to do so (Wicherts, Bakker and Molenaar 2011), especially through publications. Data withholding that occurs in academic affects essential scientific activities such as the ability to confirm published results (Campbell et al. 2002). Existing literature has discussed at length the challenges of data publication in open data initiatives. Some journals have mandated that authors should submit their data together with their results for verification. The availability of data and its reusability has been a challenge as many scholars are not willing to share data due to negativity that may result from sharing research data. A refusal to share data has been established to be related to the number of errors in the resulting manuscript (Wicherts, Bakker and Molenaar 2011); that is to say, the data that need to be reviewed the rigorous out of exactness concerns are the data not being made public. Some aspect of this is probably linked to "fear of errors being discovered" (Spies 2013, p.19). Sharing of published results from available data would go a long way toward openness in science and it will increase the reproducibility of results because some results can be dependent on how the research materials were designed. Thus, re-using the same data increases the chances of reproducing the prior results (Fecher, Freisike and Hebing 2015).

It is also widely believed that the nature of research data can highly influence the intention or motivation to share. The volume and complexity of data (especially those involving a variety of sources) might discourage scholars from sharing data (Jahnke, Asher and Keralis 2012). Conversely, some data might contain sensitive or copyrighted information, which has disclosure risks and cannot be share without proper handling (Wei 2017). Furthermore, the uniqueness of the data can also raise issues of confidentiality or ambiguity of data ownership (Parry and Mauthner 2004). As such, methods like source or volume of the data, techniques to organize, archive and reuse data must be well taken care of (Wei 2017).

There is a consensus in the literature that researchers face resistance when discussing data sharing in the context of their institutions for the following reasons: lack of access to data analysis tool; lack of research data management support; absence of well-defined technical standards; and ethical consideration that discourages sharing and reuse of data (Corti and Van den Eynden 2015). Internal research cultural factors such as unfamiliarity with appropriate methods of secondary analysis and lack of sharing culture among others can affect data sharing among scholars (Kim and Stanton 2016). Fecher, Friesike and Hebing (2015) who examined if there is a common, easy-to-locate platform on which researchers can publish data, found out that even if there is such a platform, it might not always be easy to adopt and use; therefore, an easy-to-use data sharing platform such as a well-designed features like a simple upload mechanism, or automatic data verification is important. King et al. (2011) warned that the benefits of collecting and sharing data may be undermined by infrastructural weaknesses in managing the vast types and quantities of data.

Researchers often lack the resources or the skills to make sure that the data they use, gather and produce are available for reuse – they need to have the right set of incentives to ensure effective data sharing (OECD 2013). Scholars are unsure to publish the data or to what extent it should be sanitized to protect parts' privacy. Other factors are such as insufficient time for usage of unfamiliar data (Tenopir et al. 2011), lack of reward models (Wei 2017) or reward system that recognize scholars, research funding and given credits to those who contribute to knowledge creation (Kim and Adler 2015), and extrinsic motivations for data sharing are lacking (Kim and Stanton 2016). Other factors such as perceived career advancement and scholars' altruism behavior (sense of achievement for sharing great research) have positive relationship with their data-sharing frequencies (Kim 2017; Kim and Stanton 2016). Also, in another study, Kim and Adler (2015) hypothesize that the pressure from funding agencies and journal publishers influence researchers' data sharing and there are no statistically evidence supporting their hypothesis.

Researchers (Zuiderwijk and Spiers 2019) have suggested ways of resolving the issues surrounding data disclosure. First is to make sharing trivial - in the age of Internet and digital scholarship, there should never be a technical or organizational barrier to sharing. Second, there should be measure to incentivize data sharing within the academic workflow. One of the reasons for lack of data disclosure is that little or no credits were given to data sharing. Third, there should be recognized metrics for data sharing such as page views, downloads, citation, and mentions; the incentive for sharing can then come from having a quantifiable metric that can be linked with the researcher's reputation. If sharing were practiced, errors could be detected and corrected at the initial stage of research formation, thereby reducing the effect and alleviating the fear of making them in the first place. Besides, collaboration could be valued more highly because it would increase error detection or reduce error creation and promote a culture that is less scared of failing and drives towards success (Spies 2013, p.20).

The review reflects that, in order to address the challenges and constraints surrounding open data, we need to understand researchers' readiness in terms of knowledge, level of appropriation and perceived values of open data. Hence, the current study seeks to design a survey that includes open data readiness to add value for determining researchers' awareness, practices and attitudes of open data. Obviously more studies are needed to gauge whether open data behaviours and perception are universal or perhaps country-specific, thus filling the existing research gap in understanding their acceptance, or the challenges that researchers may face.

METHOD

This study adopted a quantitative method and employed survey as the research design because it is the most frequently applied mechanism to investigate researchers' behaviours, opinions, and knowledge of a particular phenomenon such as Open Science. Respondents were recruited from five research universities in Malaysia from February to August 2018. The survey questionnaire (Appendix), which is part of a larger study that concentrated on the scholarly communication readiness of Malaysian researchers in Open Science, was developed based on a detailed literature review. The questionnaire collected data about awareness, practices and attitudes of researchers towards open data and, also elicited their demographic information (gender, age, discipline, publication in the last five years, years in academia, academic positions and research institutions). All 25 items statements that capture the variables of interest are on 5 points Likert-scale measurement, except for level of participation on open data practice (with a 3 points yes/no response). Many diverse concepts, constructs and theories exist to explain behaviours and perceptions, which encapsulate awareness, practices and attitudes, making studying this topic challenging. Therefore, the survey questionnaire developed was anchored based upon conceptual framework derived from literature related to open data readiness (World Bank 2017) and organizational change readiness (Weiner 2009; Rafferty, Jimmieson and Armenakis 2013) which cover constructs of awareness, practices and attitudes in order to see how people react to change when new behaviour or practice is introduced.

The instrument was sent to an identified panel of experts in scholarly communication for validation. The experts' eligibility is set based on their professional practices and knowledge in scholarly communication of published works (especially those who are experts in open scholarly communication, actively publishing and advocating open data). A total of five academic researchers identified as experts in scholarly communication were invited to attest the content of the instrument. An invitation e-mail was sent to the panels to seek their consent to participate in the validation process. The instrument and assessment score guides were sent upon obtaining their consent to participate. The experts examined the information about: (a) the objective of the instrument, where the questions are comprehensive enough to collect all the information needed to answer the purpose and goal of the study; (b) the content areas where it measures what it is intended to measure; (c) the level of difficulty of the questions that is appropriate for the sample; and (d) if the instrument looks like a questionnaire (Creswell 2008; Oluwatayo 2012). Feedbacks obtained served as improvement to the questionnaire.

A pilot study was conducted on 30 academic researchers at a research-intensive university in Kuala Lumpur. The questionnaire was updated based on the removal and movement of variables and items. Subsequently, corrections were made after the pilot test and were incorporated in the real questionnaire. However, it was observed that the duration to complete the questionnaire has increased from 10 minutes to 15 minutes. Upon completion of this stage, the questionnaire is ready for empirical data collection.

The sample size was determined based on Krejcie and Morgan (1970) population and sample table. With a population of 9,299 researchers in the five research universities in Malaysia (at the point of data collection), the sample size was determined as between 368-370 (confidence level=95%, margin of error =2.5%). Upon institutional approval to survey was sought, an e-mail invitation to the survey link (using google forms), with a brief introduction for the survey which hoped to encourage cooperation from participants, were distributed to 400 academic researchers' institutional e-mail addresses, which were retrieved from either university or faculty staff directory regardless of whether they provided consent or did not provide consent to be recruited. These academic researchers comprise Professors, Associate Professors and Senior Lecturers in various disciplines, and they were chosen under the assumption that they had completed significant research and were likely to be currently have research data in their possession. After three rounds of distributions, responses were received from 300 respondents; of which 165 that were incomplete were dropped from the analysis. It may possibly be inferred from this observation that respondents who did not complete the questionnaire have a total lack of knowledge of the subject of open data. The questionnaire is automatically protected against multiple participations. Consequently, 135 questionnaires were completed and used for analysis, resulting in 33.75 percent response rate, which is fairly typical of an average survey response rate (33.0%) and an e-mail survey (30.0%) (Lindemann 2018). The Cronbach's alpha score, which measures the internal consistency of all items, was satisfactory (α = 0.811). Table 1 presents data on the survey responses.

Table 1: Survey Response Rate

Total population	9299
Sample size	368-370
Oversample size	400
Clicked on the survey link	300
Incomplete survey	165
Completed survey	135
Response rate	33.75%

The returned questionnaire was analyzed using descriptive statistics. Mean values for the questions were calculated based on numeric values of the scale item with "not at all aware" (or "very untrue of me") being 1 and "extremely aware" (or "very true of me") being 5. Diverging stack bars was used to visualize the percentages in Likert questions, with the mean values shown at the end of each bar.

Table 2 presents the study demographics. The age of the respondents was used to identify whether they are early career researchers (ECRs) or established researchers. According to the working definition of Malaysian ECRs, they are "researchers between 30-39 years old, who are not more than ten years from receiving their doctorates operating without tenure" (Abrizah, Shah and Nicholas 2016, p.76). Established researchers in this study are researchers in their prime who have developed a level of independence or those that are leading in their research areas. These are researchers aged between 41 years and above and have experience more than 10 years on the academic job – as defined by the Vitae European Researchers Framework (2016, p.5).

Table 2: Demographics of Survey Respondents

Demographics		Number	Percentage
Gender	Female	85	63.0%
	Male	50	37.0%
Research experience	Early career researcher	60	44.5%
	Established researcher	75	55.5%
Academic Position	Senior Lecturers	106	78.5%
	Professors & Associate Professors	29	21.5%
Academic discipline	Sciences	94	69.6%
	Social sciences	41	30.4%

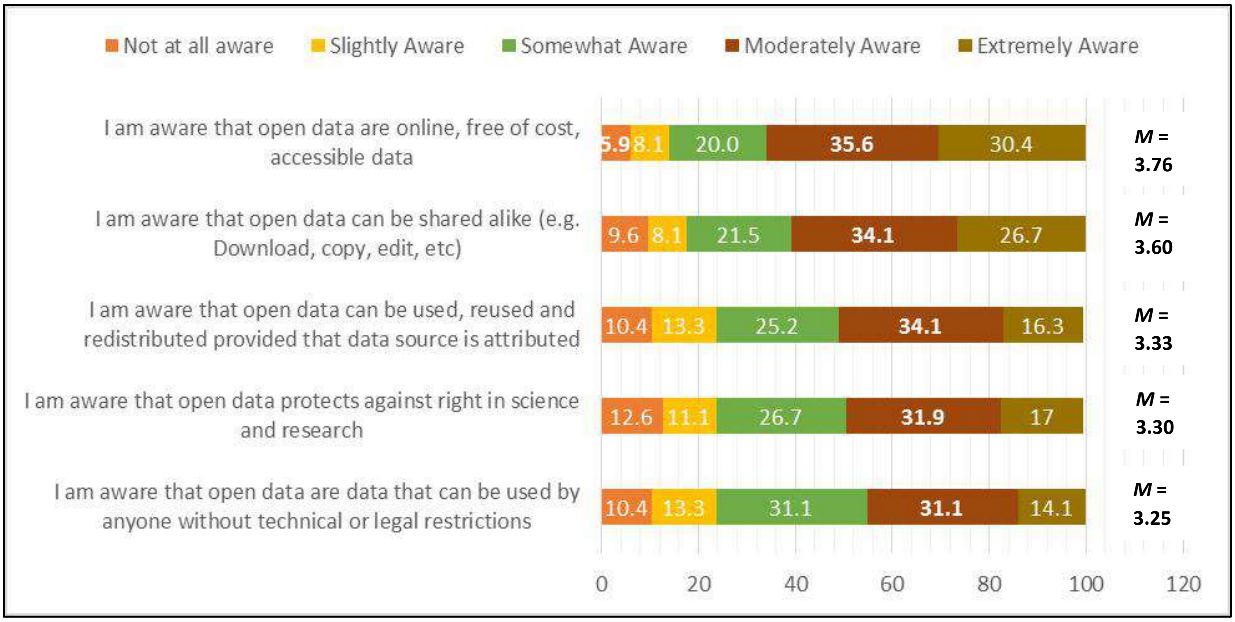
RESULTS

Researchers' Awareness of Open Data

This section examines the Malaysian researchers' awareness of open data. It is important to be aware that the concept of open data speaks directly to basic questions of ownership, responsibility, and control (Wouters and Haak 2017). Open data awareness in this study covers the understanding on awareness that open data are freely accessible; can be shared alike; can be used, reused and redistributed; protects against rights in science; and can be used by anyone without restriction.

Figure 1 presents the descriptive analysis of five item statements which is aimed at providing detailed understanding into the awareness of researchers towards open data. Considering the mean responses that reflect researchers' awareness of open data, currently there is a reasonably positive awareness (extremely aware/moderately aware/somewhat aware) that:

(a) open data are online, free of cost, accessible data (86.0%; *M*=3.76).
(b) open data can be shared alike through download, copy, edit etc. (82.3%; *M*=3.60)



1 – "Not at all aware", 2 – "Slightly aware", 3 – "Somewhat aware", 4 – "Moderately aware" and 5 – "Extremely aware". Note: The higher the mean score, the more important the activity of researchers toward open data.

Figure 1: Awareness of Open Data, according to Malaysian Researchers

However, in terms of awareness that open data can be used, reused and redistributed provided that the data source is attributed (*M*=3.33); awareness that open data protects against right in science and research (*M*=3.30); and awareness that open data are data that can be used by anyone without technical or legal restrictions (*M*=3.25) garnered less than 10 percent of extreme awareness respectively. From the findings, one may conclude that although open data awareness among Malaysian researchers is still low, a substantial portion of Malaysian researchers are still not aware or have limited awareness of open data and the potential benefits, as well as show that concerns over copyright infringement.

Researchers' Practices of Open Data Sharing

Open data sharing in this study covers the practice of making data available for used for scholarly communication by the researchers, and the reasons for doing so. In terms of practices around data sharing, the survey shows that more than one-third (39.3%) of the researchers did not share data at all. This reflects the finding that data sharing practices vary considerably among researchers with only about 16 percent researchers who acknowledged always or often make their research data open, and a high majority (45%) either sometimes or rarely share their research data (Table 3). Although the tendency to share data openly is a concern as shown from their response, findings indicate that open research data is a more established practice among the sciences and ECRs. When cross-tabulate between variables (Table 4), what emerges is a picture of very scattered practices and it is observed that:

a) More females have the tendency to make their research data open (n= 14), compared to the males (n=8).
b) More scientists always or often make their research data open (n=18), compared to the social scientists (n=4)
c) More Senior Lecturers (n=16) always or often make their research data open compared to the Professors and Associate Professors (n=6)
d) More ECRs (n=12) always or often make their research data open compared to established researchers (n=10)

Table 3: Frequency of Making/Sharing Open Data

How often do you make/share your data openly	Frequency (Percentage)
Never	53 (39.3%)
Rarely	30 (22.2%)
Sometimes	30 (22.2%)
Often	14 (10.4%)
Always	8 (5.9%)
Total	135 (100.0%)

Table 4: Frequency of Making/Sharing Open Data and Demographics Comparisons

Demographics	Never	Rarely	Sometimes	Often	Always	Total
Male	18	11	13	5	3	50
Female	35	19	17	9	5	85
Sciences	36	19	21	10	8	94
Social sciences	17	11	9	4	0	41
Senior Lecturers	45	22	23	10	6	106
Professors & Associate Professors	8	8	7	4	2	29
Early career researchers	27	8	13	9	3	60
Established researchers	26	22	17	5	5	75

Further analysis was conducted on those who reported having experience sharing data (82, 60.7%) and responded to four item statements regarding their reasons for data sharing based on a 5-point response scale (Figure 2).

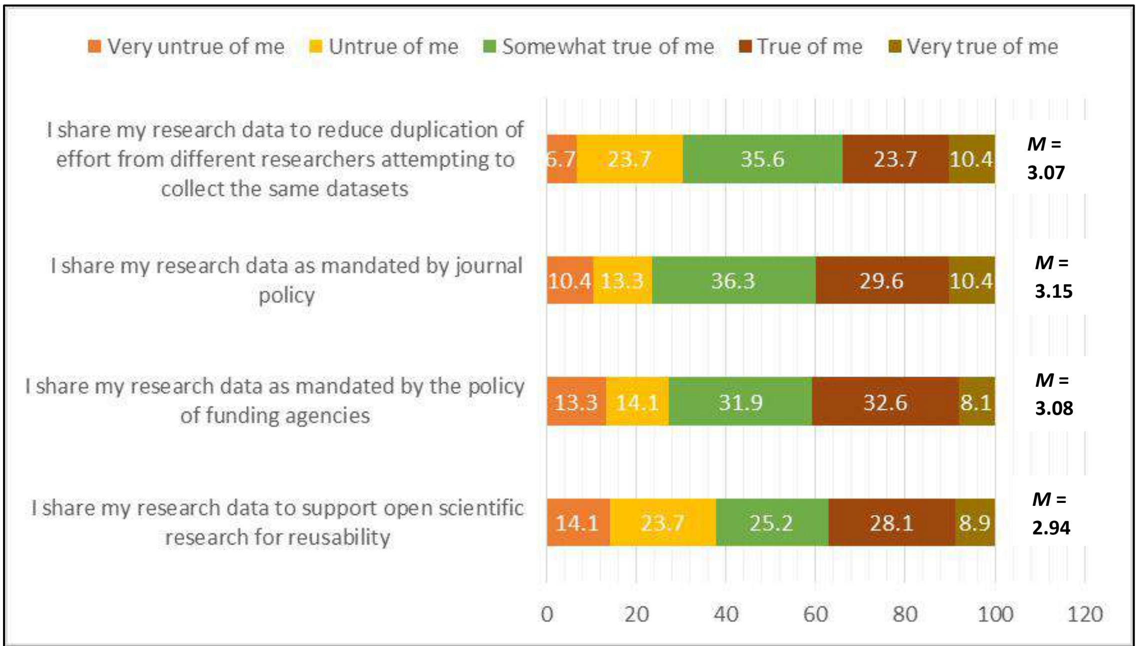
a) I share my research data to support open scientific research for reusability,
b) I share my research data as mandated by the policy of funding agencies
c) I share my research data as mandated by journal policy, and

d) I share my research data to reduce duplication of effort from different researchers.

Considering the mean responses that reflect researchers' reasons for open data sharing, currently open data mainly occurs because of (in ranked order):

a) Compliance with journal or publisher requirements (*M*=3.15)
b) Compliance with funder mandates (*M*=3.08)
c) Reducing unnecessary duplication of research (*M*= 3.07)

Interestingly, while the emphasis of open data is to support reusability of research, this does not often practice as being important (*M*=2.94). Research data is perceived as personally owned and decisions on sharing are driven by researchers, not by institutes or funders. Findings seem to indicate that open data is a reality for publishers and research funders but has not yet come a reality for researchers.



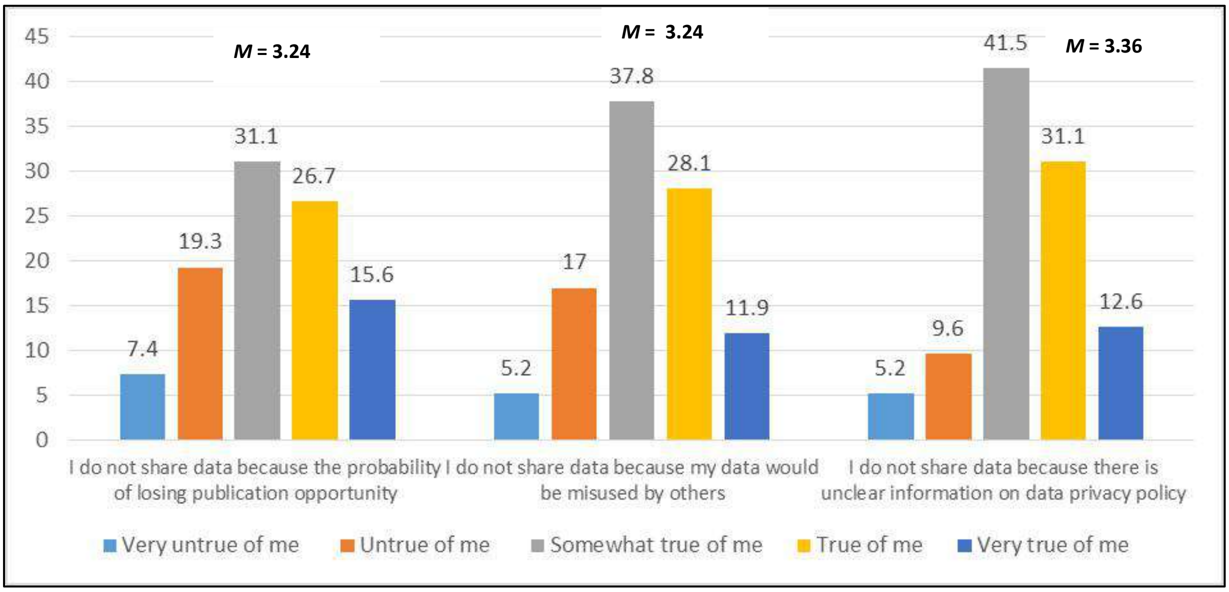
Note: 1 - "Very untrue of me", 2 - "Untrue of me", 3 - "Somewhat true of me", 4 - "True of me", 5 - "Very true of me". Note: The higher the mean score, the more important the practices of researchers toward open data.

Figure 2: Experiences of Open Data Sharing, according to Malaysian Researchers

Disincentives to Open Data Sharing

This question is a continuation of the researchers' perceptual experience in open data sharing. The survey shows that one third of the respondents did not share data at all. Since open data has not become a reality for many Malaysian researchers, one would expect, at a minimum, that barriers to sharing would discourage and disincentivize open data and slow the uptake of open data practices. Respondents were asked to rate three statements that relate to why they are not favour of sharing or publishing data, and whether these researchers share a common research profile or disciplinary background. Figure 3 illustrates that Malaysian researcher acknowledge that they do not share their research data because of:

(a) unclear information on data privacy policy (*M*= 3.36)
(b) the concern that their data would be misused by others (*M*= 3.24)
(c) the probability of losing publication opportunity (*M*= 3.24).



Note: 1 - "Very untrue of me", 2 - "Untrue of me", 3 - "Somewhat true of me", 4 - "True of me", 5 - "Very true of me". Note: The higher the mean score, the more important the practices of researchers toward open data.

Figure 3: What Disincentivize Researchers towards Open Data sharing

These finding indicate that the researchers have clear beliefs about who owns data, they feel that as the data owner prior to publication, they have more ownership over data than an institute, department, or funder. On publication of data, many researchers feel (very true of me; true of me; somewhat true of me) that they would be losing publication opportunity (73.4%). Legal and ethical concerns are cited as reasons for not publishing research data alongside an article: a substantial proportion of the respondents answered that they do not like the idea that others might abuse (let alone take credit for it) (77.8%) and a high majority were unclear about data privacy policy (85.2%).

Further analysis was conducted on those who have major concerns about making or sharing data openly (very true of me; true of me; somewhat true of me). Table 5 presents the findings. It was evidenced that females (n=85) have more concerns in open data sharing. For instance, more females have concern about losing publication opportunity received (n=61; 45.1%), concerns about data misuse by others received (n=66; 48.9%) while concern about data privacy received (n=71; 52.6%) on sharing research data as compared to their male counterparts (n=50; 28.1%, 28.9%, 32.6% respectively). Accordingly, established researchers were more in the study (n=75) and their concerns about sharing data is relatively high for example concern about losing publication opportunity garnered (n=54; 40.0%), concern about data misuse by others received (n=57; 42.2%) and concern about data privacy received (n=64; 47.4%) as compared to the ECRs (n=60) for the same feelings (n=45, 33.3%; n=48, 35.6%; n=51, 37.8% respectively). More so, in terms of discipline, the sciences (n=94) have more concerns about losing publication opportunity (n=70; 51.9%), concern about data misuse by others received (n=74; 54.8%) and concern about data privacy received (n=80; 59.2%) as compared to the social scientists (n=41). On the contrary, fewer Professors and Associate Professors (n=29) have less concerns about losing publication opportunity (n=20; 14.8%), probably because they are already established in their careers and versatile in scholarly publishing. However, they also have concerns about data misuse by others (n=23; 17.0%) as well as concern about data privacy received (n=25; 18.5%). More senior lecturers (n=106) have concerns with these issues (n=79, 58.5; n=82, 60.7%; n=90, 66.7% respectively). Again, as illustrated, research data seem to be perceived as personally owned and decisions on sharing are driven by researchers, not by their institutions or funders. Findings seem to indicate that the concern for sharing data is a reality for researchers, especially among the established, the sciences and the female researchers.

Table 5: Researchers' Major Concerns in Open Data Sharing and Demographics Comparison

Demographics	Losing publication opportunity	Data misused by others	Data privacy
Male	38	39	44
Female	61	66	71
Sciences	70	74	80
Social sciences	29	31	35
Senior Lecturers	79	82	90
Professors & Associate Professors	20	23	25
Early career researchers	45	48	51
Established researchers	54	57	64

Researchers' Attitudes towards Open Data

Built from studies on Open Science perceptions (Ostaszewski 2014; Martinez and Poveda 2018), the authors determine researchers' attitudes towards open data from statements that reflect (a) the deficiencies of the current system which could be overcome by open data; (b) the implications of open data; and (c) the barriers to the promotion and positioning of open data. As reflected from the means score of each statement in Figure 4, findings on Malaysian researchers' open data attitude converge towards the fact that the researchers have generally accepted the idea of open data and that they consider it as globally beneficial for progress in science, but they believe open data has constraints that prevent its widespread proliferation.

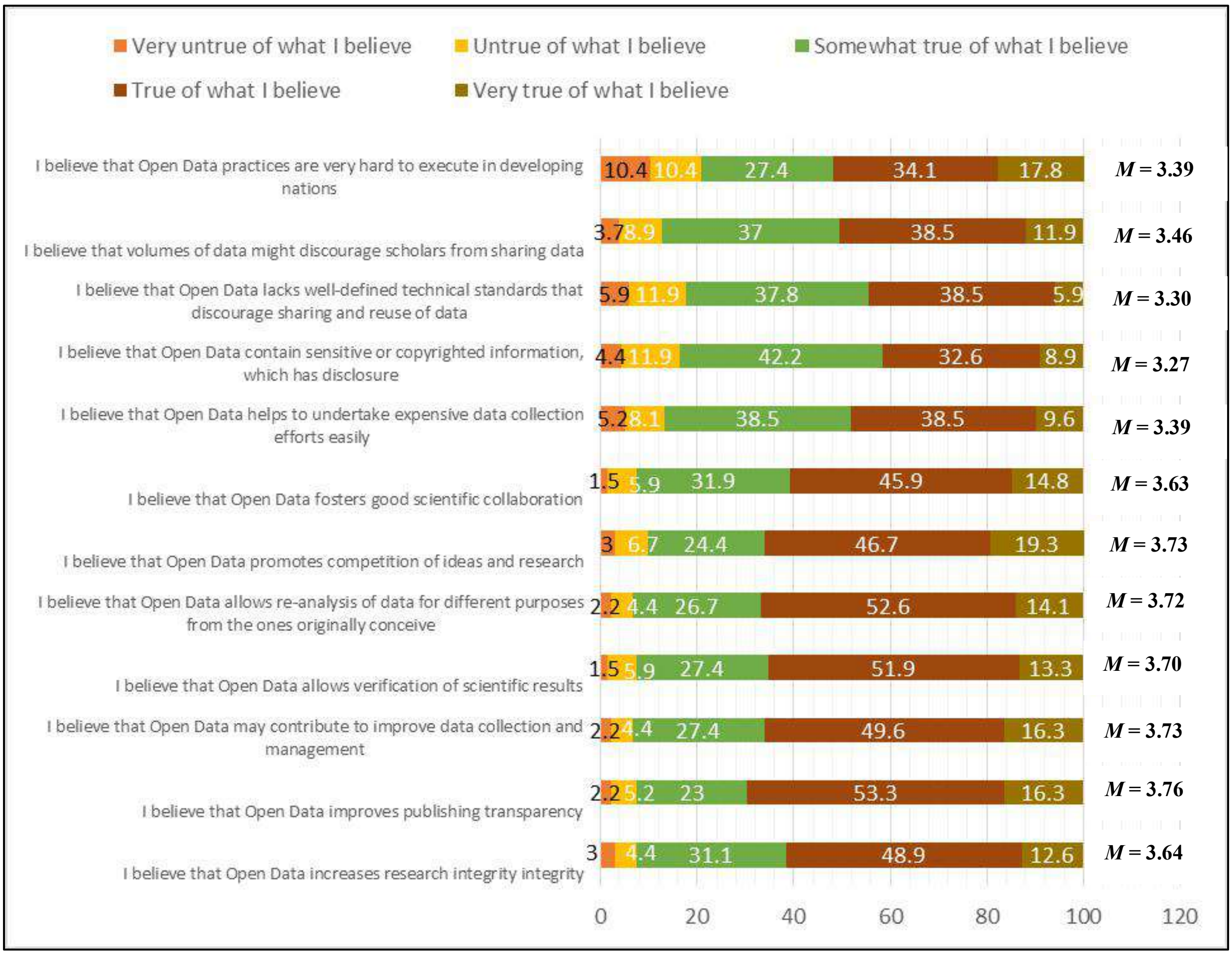
Malaysian researchers considered the following to be the deficiencies of the current system that open data could overcome (very true of what I believe / true of what I believe):

a) improves publishing transparency (69.6%, *M*=3.76)
b) allows re-analysis of data for different purposes from the ones originally conceived (66.7%, *M*=3.72)
c) improves data collection and management (65.9%, *M*=3.73)
d) allows verification of scientific results (65.2%, *M*=3.70)
e) increases research integrity (61.5%, *M*=3.64)
f) helps to undertake expensive data collection efforts easily (48.1%, *M*=3.39)

They believed that (very true of what I believe /true of what I believe) the implications of Open Science and its impact on research are as follow : it promotes competition of ideas and research (66.0%, *M*=3.73); and it fosters good scientific collaboration (60.7%, *M*=3.63). Based on these findings, it can be said that respondents viewed open data in a positive way.

While the benefits of open data may be recognized, the barriers are clear as well. They believed that (very true of what I believe / true of what I believe) the barriers related to the promotion and positioning of open data are as follows:

a) open data practices that are very hard to execute in developing nations (51.9%, *M*=3.39)
b) volumes of data might discourage researchers from sharing data (50.4%, *M*=3.46)
c) it lacks well-defined technical standards that discourage sharing and reuse of data (44.4%, *M*=3.30)
d) it contains sensitive or copyrighted information, which has disclosure (41.5%, *M*=3.27).



Note: 1 - “Very untrue of what I believe”, 2 - “Untrue of what I believe”, 3 – “Somewhat true of what I believe”, 4 - “True of what I believe”, 5 - “Very true of what I believe”. Note: The higher the mean score, the more important the attitude of researchers toward open data.

Figure 4: Attitudes towards Open Data, according to Malaysian Researchers

DISCUSSIONS AND CONCLUSIONS

The open data behaviours and perceptions of Malaysian researchers indicate that overall it is apparent that there is a reasonably positive awareness, although the tendency to share research data openly brings with it many concerns and challenges for researchers. While open data is clearly established as a topic that is now in the mainstream for researchers (Fane 2019), a substantial proportion of Malaysian researchers are still not aware or have limited awareness of open data and the potential benefits. The reason for not sharing data openly could be as a result of not having access to their data anymore, not being able to publish findings from their data especially if another researcher uses it first affecting their own ability to publish. Findings indicate that academic discipline and research experience affect the affinity of open data and its sharing practices, as it is a more established practice among the sciences and ECRs. This could be as a result of their open scholarly communication behaviours such as promoting and fostering scientific research and collaborations, as well as attitudes with regard to the motivation to improve scientific transparency to go in line with the likelihood of stand-in on any innovative beliefs, especially to make their footings known in academe and as the harbingers of new wave in their chosen fields (Nicholas et al. 2017; 2019).

There is clearly a lack of understanding among the respondents around what makes open data sharing essential. The motivation was partly compliance with journals publisher and research funders. This may be due to the clear steps most publishers take today to increase motivation to share data, that make it worth a researcher's time and effort to open up their research (Baynes 2019). Interestingly, while the emphasis on open data is to support reusability of research, this practice does not often viewed as being important. Research data are perceived as personally owned and decisions on sharing are driven by researchers, not by their institutions or funders. Findings seem to indicate that open data is a reality for publishers and research funders but has not yet become a reality for researchers.

While Malaysian researchers in this study recognize the benefits of sharing data in the form of the deficiencies of the current system that open data could overcome, the barriers in the promotion and positioning of open data are clear as well. This is corroborating with the report from Elsevier and Centre for Science and Technology Studies (CWTS) which reveals that although the benefits of open research data are well known, in practice, confusion remains within the researcher community around when and how to share research data (Wouters and Haak 2017). This may be as a result of scholars withholding attitudes toward sharing of data, as identified in past studies (Kim and Stanton 2016; Tenopir et al. 2011; Wicherts et al. 2006). Malaysian researchers acknowledge that they do not share their research data in particular due to unclear information on data privacy policy, trust in what others may do with researchers' data if it is made openly available, and the probability of losing publication opportunity. The biggest barrier to research data sharing and reuse seems to be a matter of trust, which was also found in the Digital Science study (Hrynaszkiewicz 2019). However, in the study of Ostaszewski (2014), majority of the respondents claim that sharing research data in research practice may positively contribute to a progress in their discipline. Such a high level of support complies with the main arguments addressed by advocates of Open Science, that giving and sharing research data would give extra boost to the process of scientific progress.

From the foregoing, it is obvious that the research community has started the open data journey, but open data is yet to be given its pride among Malaysian researchers. We can convincingly reason out that the researchers view some hindrances to open data, which might be as a result of lack of training and incentives for data sharing. Implementing open data in research requires a level of readiness among the researchers, as well as a cultural transformation in the way universities collect, share, and consume information. The issues of cultural and national concerns pose a major challenge to open data sharing. Concerns about misuse and the fear of losing publication opportunity alongside the lack of incentives should be addressed urgently by the funders and advocates of open data. Policies that incentivize the use and reuse of open data sharing practices, as well as tools and guidance to support data sharing and a strong incentives and rewards to implement open data practice among scholars should be encouraged.

This paper is the first national survey that elicits Malaysian researchers' from research-intensive universities view with regard to open data behaviours and perception. Its limitation is rooted in the sample, which is relatively small and not necessarily representative of the Malaysian research population as a whole. However, it provides a much needed snapshot of open data sharing practices today and provides a timely complement to national studies on Open Science readiness. Open data is a key component of Open Science, but cultural change needs to happen for Open Science to become the norm in research practice. Malaysia, as a nation that has achieved an inspiring level of growth within the research sector (Elsevier 2020) and research competences, can realize the vast amount of social-economic benefits of open data by moving towards providing and motivating the academic researchers on the guiding principle that will allow open data as a matter of routine rather than exception that is obtainable at the moment. Insights gained from this study would be useful for researchers – as well as their institutions, government and funders to better understand how to best serve data sharing needs, and the philosophy involves when it comes to research data sharing among the scholars, and how to manage challenges that often arise. Malaysian scholarly journal publishers are not left behind in the resistance researchers face when submitting their data as publishing requirements. There should be an alliance between the publishers and the funders to enable data sharing to be more effective and rewarding and to ensure compliance for data publishing. Future studies should investigate the importance or rewards for data sharing among the researchers' institutions, also, studies bridging the gap between policy and practices of open data sharing should be examined. It is worth considering, at least, why researchers may not respond to a data sharing request.

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APPENDIX – Questionnaire

S/N	Statements					
	Statements on level of participation in open data practices. Note: (1) No, and Not Considered; (2) No But Considered; (3) Yes					
1	Have you ever made your data open before?	1	2	3		
	Please indicate [√] your frequency of practices in the following statement. Note: (1) Never; (2) Rarely; (3) Sometimes; (4) Often; (5) Always					
2	How often do you make your data open?	1	2	3	4	5
	Open data are data that can be used by anyone without any constraint (financial or official). **Please tick [√] to indicate your response Note: (1) Not at all aware; (2) Slightly Aware; (3) Somewhat Aware; (4) Moderately Aware; (5) Extremely Aware**					
	I am aware that open data…					
3	are online, free of cost, accessible data	1	2	3	4	5
4	can be shared alike (e.g. download, copy, edit etc)	1	2	3	4	5
5	can be used, reused and redistributed provided that the data source is attributed	1	2	3	4	5
6	protect against right in science and research	1	2	3	4	5
7	are data that can be used by anyone without technical or legal restrictions	1	2	3	4	5
	I share my research data…					
8	to support open scientific research for reusability	1	2	3	4	5
9	as mandated by the policy of funding agencies	1	2	3	4	5
10	as mandated by the journal policy	1	2	3	4	5
11	to reduce duplication of effort from different researchers attempting to collect the same data sets	1	2	3	4	5
12	I do not share data because the probability of losing publication opportunity	1	2	3	4	5
13	I do not share data because my data would be misused by others	1	2	3	4	5
14	I do not share data because there is unclear information on data privacy policy	1	2	3	4	5
	Please indicate (√) your perception of the following statement about open data Note: (1) Very untrue of what I believe; (2) Untrue of what I believe; (3) Neutral; (4) True of what I believe; (5) Very true of what I believe					
	I believe that open data …					
15	increases research integrity	1	2	3	4	5
16	improves publishing transparency	1	2	3	4	5
17	may contribute to improve data collection and management	1	2	3	4	5
18	allows verification of scientific results	1	2	3	4	5
19	allows re-analysis of data for different purposes from the ones originally conceive	1	2	3	4	5
20	promotes competition of ideas and research	1	2	3	4	5
21	fosters good scientific collaboration	1	2	3	4	5
22	helps to undertake expensive data collection efforts easily	1	2	3	4	5
23	contain sensitive or copyrighted information, which has disclosure	1	2	3	4	5
24	lack well-defined technical standards that discourage sharing and reuse of data	1	2	3	4	5
25	volumes of data might discourage scholars from sharing data	1	2	3	4	5
26	practices are very hard to execute especially in developing nations	1	2	3	4	5

Demographic Information

Instruction: Please fill in the space provided or tick (√) the answer that BEST describe you

Age: ☐ ≤ 30 ☐ 31-35 ☐ 36-40 ☐ 41-45 ☐ ≥ 46	**Gender:** ☐ Male ☐ Female **Years in Academia:** ☐ < 1 year ☐ 6-10 years ☐ 1-5 years ☐ 11 ≥ years
Academic Position ☐ Research Officer ☐ Research Assistant ☐ Senior Lecturer ☐ Post Doctorate ☐ Research Fellow ☐ Associate Professor ☐ Professor ☐ Others, please specify ……………………… …………	**Discipline:** What Subject Discipline are you specialized in? [Please Specify] ………………………………… **Publication: How many publications do you have in the last 5 years?** ☐ None ☐ 1 - 3 ☐ 4 - 6 ☐ 7 and above [Please Specify]………………………
Your Research University: ☐ Universiti Malaya (UM) ☐ Universiti Sains Malaysia (USM) ☐ Universiti Kebangsaan Malaysia (UKM) ☐ Universiti Putra Malaysia (UPM) ☐ Universiti Technologi Malaysia (UTM)	**Email: Optional (For Acknowledgements only):** ……………………………………………………………… ………………………………………………………………

Thank you for your willingness to participate in this survey

TITLE	SOURCE
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TOWARDS THE RIGHT STANDARDS

The intersection of open science, responsible research and innovation, and standards

MICHELE GARFINKEL

The introduction of standards in research and development leading to new products or innovative processes can be thought of as a particularly technical approach to framing scientific enterprises. At the other end of the spectrum, open science or responsible research and innovation may be initially thought of as concepts with no underlying technical approaches to support them. In reality as currently practiced, the development and use of standards engages significant non-technical aspects, needing to take into account research cultures or desired societal outcomes. Similarly, open science, and responsible research and innovation can operate using very practical and technical approaches. This essay focuses at the intersections of these concepts to try to contribute to larger discussions in both the research and governance communities as to how researchers should conduct their research, and what respective responsibilities of researchers, their institutes, and their supporters are.

Keywords: standards, open science, responsible research and innovation.

OPEN SCIENCE, RESPONSIBLE RESEARCH AND INNOVATION, AND STANDARDS

While there is significant overlap in the framings, purposes, and outcomes of the concepts *responsible research and innovation* (RRI) and *open science* (OS), we can roughly separate them initially as focusing on science for and with society in the former case, and the process of research and disposition of findings in the latter. To be clear, society as a whole benefits from open science, and we can certainly think of it as being critical in responsible research and innovation. It is useful to separate these to some degree, however, for the purpose of understanding whether and how the use of standards could influence the robustness of RRI and OS.

Open science includes many stakeholders and their representative communities may have different working definitions of open science. Most inclusively, open science can be thought of as a way to make science as accessible and responsive as possible to society. Such accessibility will of course require some discretion to protect sensitive or potentially dangerous information from being unnecessarily widely shared.

The pillars of open science as well may vary between stakeholder communities, but in general all will include open access to publications, open data availability, educational resources on how to participate in open science, a review component to assure quality and integrity, and citizen scientist participation.

«Open access and open data in principle can be handled as technical issues, with their own sets of standards»

All of these areas are currently under discussion at the European level (for example, in the Open Science Policy Platform, a high-level advisory group to the European Commission Research Commissioner) and at national levels (for example, in the countries participating in the Council for Open Science Coordination) (CoNOSC, 2020; European Commission, 2020).

While these discussions may come to different conclusions about the best ways to achieve open science, there will certainly be some areas where it will be desirable to have those processes at least aligned, if not standardized. The pillars of open data, particularly as captured in the FAIR data concept (findable, accessible, interoperable, reusable), would seem to in fact require standards to assure its viability.


Greg Emmerich

Open science, as a concept, can be thought of as a way to make science as accessible and responsive as possible to society by different means, from open access to publications to promoting citizen science. Above, open science logo for the Open Source Initiative.

«What *open* means with respect to access to research papers remains remarkably fuzzy»

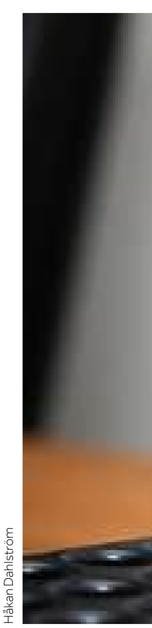
Responsible research and innovation provides both analytic and practical frameworks to consider when undertaking research. We can consider RRI from the analytic perspective of social sciences (see Owen et al., 2012, an early and comprehensive description of RRI), but we can think of it as well from the view of researchers doing work that is encompassed by the concepts of RRI. In fact, while RRI is frequently described by the pillars that the EU has used to functionalize its definition (public engagement, open access, gender equality, ethical issues, education), a 2014 flyer (European Commission, 2014) describing RRI as Europe's ability to respond to societal challenges points more toward the actions required by researchers themselves («choose together», «do the right "think" and do it right») as a defining factor. Interestingly, this document begins to touch on a need for standards (especially, in aligning not only outcomes but processes) to assist researchers in accomplishing these tasks.

It is quite reasonable to think about standards in the first instance as technical solutions to technical problems. We can avoid having ten different stoppers for laboratory glassware by standardizing openings and closures. Industries can work to assure that companies can compete on new ideas and improved products by enforcing standards as was famously and successfully accomplished by the semiconductor consortium Sematech (Hof, 2011). But could we have the equivalent of an ISO standard for RRI?

A problem in thinking about standards for RRI is in the conceptualization of standards as applying to technical and, usually, quantitative areas. Thus, if we think of this question as where can we apply standards, it is much easier to imagine standards for open science than for RRI. The concepts underlying OS are much more technical, at least on first inspection, than those of RRI. Open access and open data, two major areas that OS proponents want to accomplish, in principle can be handled as technical issues, with their own sets of standards. Open data is already described as being (or not being) FAIR; that is, as mentioned before, findable, accessible, interoperable, and reusable. These principles provided by Force11 (2017) offer in essence a set of standards and metrics for defining whether those standards have been met.

It would then not be that far of a step to capture these in a standard. The last and hardest step of course is the adoption of such standards universally. In some aspects, the communities concerned about FAIR data (indeed, most researchers) are at least partway there already in the use of data management plans. When employed, such plans act not as an obstacle to accomplishing research but rather as an inherent part of research planning, in the same way that technical standards are simply taken into account in research planning.

As researchers we can think then also about whether standards for open publishing are possible and desirable. The discussions around open access have been percolating for decades, and at this point, it is probably reasonable to say that there is no objection to publishing research findings in a way that is as open and quickly accessible as possible, taking into account potential private or security issues.


Håkan Dahlström

However, what *open* means with respect to access to research papers remains remarkably fuzzy. The lack of agreement around open access was on display during the discussions concerning Plan S, a proposal by a group of funders with respect to requirements for posting papers in open access if money from those funders was to be used. This group includes currently seventeen national funders and with support expressed by the European Commission, including one of its funding bodies, the European Research Council. The singular target of Plan S, as described by the group of funders called cOAlition S, is that «With effect from 2021, all scholarly publications on the results from research funded by public or private grants provided by national, regional and international research councils and funding bodies, must be published in Open Access Journals, on Open Access Platforms, or made immediately available through Open Access Repositories without embargo». (cOAlition S, 2019).

This is accompanied by ten principles and work on the implementation is ongoing.

What was particularly interesting in the discussions around the first draft of the plan was an apparent lack of agreement around any particular aspect. Is the concept of *open* in a hybrid journal sufficient (that is, researchers or institutions pay an otherwise subscription journal for a specific article to be open access)? Is it acceptable for the community to use hybrid journals for a while, but not after an arbitrary end date? Are preprints an acceptable alternative? Or posting of a pre-acceptance manuscript on one's own server? What was compelling in this discussion was not so much the details (though these are important) but that the community had been talking about this issue for so long, and those discussions somehow could not be synthesized into policy, even by a relatively small group of important actors.

Does this indicate that even loose standards («principles», «best practices», and the like) would be difficult or impossible for open access? Or can we imagine a case that the definition of *open* is left up to individual funders (as many have policies for now) or even to research sectors? These solutions of course move away from the idea of standards as universal.

When we think about standards, we tend to see them as technical solutions to technical problems, such as standardising laboratory glassware for a more efficient lab work. But could we have the equivalent of an ISO standard applied to the practices and methods of responsible research?

Science Europe

Nowadays, there seems to be no considerable objections to publishing research in a way as open and quickly as possible. However, what *open* means remains under debate. Even during the discussions concerning Plan S, a proposal by a group of funders – the European Research Council among them– with respect to requirements for posting papers in open access if money from those funders was to be used, there was some lack of agreement around many aspects, including what open publishing entailed.

APPLYING NON-TECHNICAL PRINCIPLES TO IMPROVING TECHNICAL STANDARDS

As communities are considering the role that standards may play in expanding and improving open science and responsible research and innovation, we can also look at the reverse. How can the principles of open science, or the structures of RRI, help us to improve standards? The European-funded project BioRoboost (Fostering Synthetic Biology Standardisation through International Collaboration) (2019) in which I participate is focused on improving the standardization of biological systems, broadly wrought. The earliest framings of synthetic biology focused on emphasizing the *engineering* part of *genetic engineering*. If this is to eventually be functionalized, synthetic biology will require standards, as engineering does.

We can make a parallel then with any system of specification. One useful comparator might be FAIR data. Specifically, what do we need in the specification and execution of synthetic biology experiments and applications to assure that each «thing», be it a chassis, a measurement device, or an approach to risk assessment is, in the broadest sense, findable, accessible, interoperable, and reusable. As a synthetic biology research community, we are unlikely to achieve all of these quickly and comprehensively. But some lessons that we can take from the discussions around open science are very useful, particularly with respect to how open science is not exclusive of high quality and responsible science. Our communities may need, though, to create modified or new structures to assure that quality and responsibility. One area where these concerns are particularly noted is respect to peer review, as sharing of research results now no longer occurs only through peer-reviewed journals.

Looking toward the framework of RRI, and more generally issues around responsible conduct

Michele Garfinkel

Above, break during the last BioRoboost workshop held in October 2019. This European funded project aims at improving the standardization of biological systems within the frame of synthetic biology. For this, several questions must be discussed, such as why standards are necessary at all, or which standards should be invented specifically for synthetic biology.

of research and research integrity, will be even more fruitful for thinking about how to approach standardization. We learn from rigorous literatures that mechanisms for working through even the most technical questions are subject to sectoral, cultural, gender, and national biases. Within BioRoboost (and in many other projects) we are trying to apply these lessons in approaching all of the concerns about the usefulness of standards for researchers.

Further, we can use the development of standards to assist an understanding of the role of open science in promoting and assuring responsible conduct of research broadly. It is frequently said (though with not enough evidence yet to draw conclusions) that openness will help to improve integrity because «everyone can see». But science has not been hidden per se to date, only looked at in perhaps a more compartmentalized manner. As just one example from a small set of journals, in post-peer reviewed, pre-publication primary research papers, about 20 % contain aberrations that must be pursued by journal editors prior to acceptance. About half of these are a result of authors manipulating images or data in such a way to make the paper «look nicer», but on removal of these manipulations, the results stand. The other half contain varying degrees of manipulations, from beautification to outright fraud, that may change the conclusions (Pulverer, 2015). There is no reason to think such aberrations do not occur in a more «open», less overseen literature. Standards of course are much more tightly overseen, but there are still differences in how standards develop between communities that may remain unresolved.

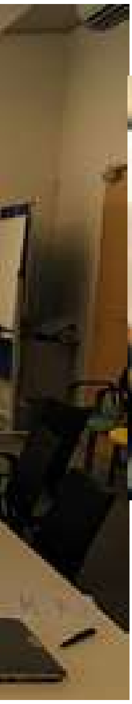
«It is only through experimentation that the community can definitively assess the value of particular standards»

A key realization with respect to research integrity generally and even RRI more specifically is that in order to operate within those frameworks, researchers need both training and tools. It is easy to be disillusioned about a 20 % aberration rate, but if researchers do not know what constitutes an improper manipulation, we cannot really hold that against them. Similarly, it is becoming rapidly apparent that the need for standards, the uses of standards, and the roles of individuals and communities in assurance of proper and necessary use will require training. In principle, that training would fit in easily with more general training in responsible conduct of research. Unfortunately, the requirements for this type of training remain idiosyncratic and vary widely between funders, institutions, and countries. This is an area where those concerned about standards could be in front and work towards providing training at least within the community, for the value of that demonstration, but also for the important substantive reasons.

The distance then between applying a technical standard to solve a technical problem and asking for a process standard (e.g., «think about your problem engaging a set of stakeholders prior to submitting a grant proposal») may not be so far. The difference rather would be in how users (researchers) would view the use of those processes. Is this something that can be regulated? Or, is «think about this problem» something that researchers simply do as a matter of course, and trying to add a step to standardize it in this case does become excessive rather than helpful?

WHOSE RESPONSIBILITY?

Contemplating how responsibilities may be undertaken, it may be useful to think about responsibility's component parts: the desired outcome, and the performer(s) of particular actions to get to that outcome. Identifying «someone» or «an entity» as needing to be responsible is an important first step. But those




Louis Reed

To operate within the responsible research and innovation framework, researchers need training and tools. If researchers do not know what constitutes an improper behaviour or even a manipulation of results, we cannot really hold that against them.

identities need to be defined earlier rather than later. It will matter whom or which agency is specifically responsible, for example, to assure that a standard will work in an open science environment or that researchers are properly trained on how to employ standards in their work.

A perhaps tangential but important responsibility regards the type of work that researchers could or should do to contribute to improve standards for the entire community. Different research and organizational sectors approach the issue of routine or non-novel work in different ways. In for-profit organizations, this type of work may be baked in to the overall work plan, and appropriate hiring assures that work is done. But, for example, in the academic sector, where the underlying research to support standards development might need to happen, it is difficult to direct that such research happens. Incentives, particularly relating to the provision of significant grants, could improve that situation. But ultimately such research must be seen as being valued by the community, and not as an appendage (Garfinkel, 2012).

Finally, a clear responsibility of the research community must be to help decision-makers to understand where standards are necessary and how the research community should be involved in their development. One important and underexplored problem with imposing standards (or regulation, or any «rule» most broadly scoped) is that they definitionally decrease diversity. Sometimes this is good: a «diversity of regulations» would not a priori be desirable or helpful. But in other cases, standardization can destroy diversity that was inherently necessary in the system. In some cases, that diversity allows for competition, benefiting, for example, consumers or any users of a product or technology.

Particularly in research, a period of competing standards can be healthy. It is only through experimentation that the community can definitively assess the value of particular standards, and that experimentation, given the nature of research, will take time. Part of our collective responsibilities then must relate to protecting the ability to try different approaches, while essentially simultaneously working to assure that useful standards are imposed and enforced as needed. This is not easy or straightforward. But particularly in emerging areas of biotechnology research where concerns about a particular approach's usefulness, safety, or societal desirability are already key parts of policymaker discussions, this last piece of supporting some ambiguities around standardization followed by robust adoption should contribute to improved governance, and societal outcomes.

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Open peer review: promoting transparency in open science

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Abstract

Open peer review (OPR), where review reports and reviewers' identities are published alongside the articles, represents one of the last aspects of the open science movement to be widely embraced, although its adoption has been growing since the turn of the century. This study provides the first comprehensive investigation of OPR adoption, its early adopters and the implementation approaches used. Current bibliographic databases do not systematically index OPR journals, nor do the OPR journals clearly state their policies on open identities and open reports. Using various methods, we identified 617 OPR journals that published at least one article with open identities or open reports as of 2019 and analyzed their wide-ranging implementations to derive emerging OPR practices. The findings suggest that: (1) there has been a steady growth in OPR adoption since 2001, when 38 journals initially adopted OPR, with more rapid growth since 2017; (2) OPR adoption is most prevalent in medical and scientific disciplines (79.9%); (3) five publishers are responsible for 81% of the identified OPR journals; (4) early adopter publishers have implemented OPR in different ways, resulting in different levels of transparency. Across the variations in OPR implementations, two important factors define the degree of transparency: open identities and open reports. Open identities may include reviewer names and affiliation as well as credentials; open reports may include timestamped review histories consisting of referee reports and author rebuttals or a letter from the editor integrating reviewers' comments. When and where open reports can be accessed are also important factors indicating the OPR transparency level. Publishers of optional OPR journals should add metric data in their annual status reports.

Keywords Open peer review · Scholarly communication · Journal editorial policies · Open access · Peer review transparency · Transparent review models

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JEL Code C80

Introduction

Peer[1] review represents one of the foundations of modern scholarly communication. The scrutiny of peers to assess the merits of research and to provide recommendations for whether research exhibits sufficient rigor and novelty to warrant publication is intended to reduce the risk of publishing research that is sloppy, erroneous or, at worst, fabricated. The process of peer review is intended to help improve the reporting of research and to weed out work that does not meet the research community's standards for research production.

Traditionally, peer review uses forms of blinded review where parties involved remain anonymous to reduce bias in the evaluation process. The most extensive form of blinded review, triple blind, anonymizes the process so that the author(s), reviewer(s) and the handling editor(s) are not aware of each other's identities. A more common implementation is double blind peer review, where the author(s) and reviewer(s) are not aware of each other's identities. To ensure author anonymity, authors must remove all content that might identify them to any reviewer. Single blind review is also commonly practiced, where reviewers are aware of the identities of the authors, but the authors do not know who has reviewed their manuscript. The question arises whether blinded peer review reduces bias and results in a more objective review. For authors, blinded reviews are like a black box. Blinding of reviewer identities may allow reviewers to use their anonymity to deliver more critical reviews or to write reviews that lack rigor because authors and readers will not know who the reviewers are. On the other hand, requiring reviewers to identify themselves may encourage greater accountability or could cause reviewers to blunt their criticisms (van Rooyen et al. 1999).

The open science movement has endeavored to increase the transparency of the production of scientific knowledge and to make products of scientific inquiry more broadly available. The most visible aspect of the open science movement to date has been open access (OA), where the products of scholarship are made freely available through open access journals or repositories. More recently, efforts have extended to the availability of open data and software, where datasets are shared and re-used. One of the last components of open science to be adopted is open peer review (OPR), where aspects of the peer review process, which have traditionally been hidden or anonymous, are made public.

Debate about the benefits of and concerns about OPR have been evident in scholarly communication. Malone (1999) believed that a fully open system increases responsibility and accountability and protects all parties more equitably: "Openness in peer review may be an idea whose time has come. What do you think?" (p. 151). At the 2016 Annual Meeting of the Association for Information Science and Technology, a panel of well-known scientists and editors engaged in a conversation and debate with conference attendees on the emerging open peer review innovation in the era of open science (Wang and Wolfram 2016). Similarly, at the 8th Peer Review Congress (2017), leaders in academic publishing

[1] This paper represents a greatly expanded version of a study presented at the 17th International Society for Scientometrics and Informetrics Conference held in Rome, Italy in September 2019 (Wolfram et al. 2019).

held a panel on "Transparency in Peer Review." The panelists discussed the various shades or spectrum of transparency in open peer review practices. Also touched upon was the lack of transparency in research proposal reviews, especially for private foundations. Attendees at the Congress raised another important question: "Should there also be transparency in reviewing reports of rejected manuscripts if they are a part of the scholarly ecosystem?" Launched in 2015, Peer Review Week (2017) set its theme for 2017 as Transparency in Review. Clobridge (2016) compared the benefits and challenges of OPR for authors, reviewers, and readers. She also cited three major players of OPR, *PeerJ*, *F1000Research*, and *ScienceOpen*. She noted that "Open peer review, while still a relatively new phenomenon, is catching the interest of many researchers and appears to be gaining momentum as part of the next wave of open knowledge and open science" (p. 62).

Will OPR become a more common scholarly practice like open access and open data in open science? Further research is needed to understand the concept of OPR and its diverse implementations by publishers as well as the perceptions and attitudes of scientists as authors and reviewers. The purpose of this study is to conduct a thorough search for and analysis of current OPR journals to address the following research questions:

1. What is the current state of OPR?
2. What has been the trend for OPR adoption?
3. Who are the early adopters of OPR?
    a. Which disciplines have adopted OPR?
    b. Which publishers are the front runners or leaders in OPR adoption?
4. How transparent are the emerging OPR implementations?
    a. Do these journals adopt open reports?
    b. Do these journals adopt open identities?

Literature review

In the era of digital open science, OA journals have mushroomed on the Web. Do these journals provide access to quality research? Does this openness extend to peer review and, if so, how is peer review conducted by these OA journals? In a sting-operation experiment, *Science* correspondent John Bohannon (2013) found that of the 304 versions of a fabricated paper with flawed research submitted to 304 OA journals, 255 submissions received a decision (the mean for acceptance was 40 days; the mean for rejection was 24 days). Surprisingly, 157 journals accepted a version of the paper. Was this reflected in the peer reviews? Only 36 reviews recognized the paper's scientific problems whereas "about 60% of the final decisions occurred with no sign of peer review" (p 64). Rupp et al. (2019) concluded "although predatory publishing did not exist ten years ago, today, it represents a major problem in academic publishing" (p 516). There is an "apparent rise in scientific fraud" (Naik 2011) as well as peer review fraud. A "peer review ring" scandal resulted in the retraction of 60 articles at once by a prestigious journal (Barbash 2014). BioMed Central discovered fake peer reviewers involved in 50 manuscripts and took actions to investigate and retract 43 papers (Lawrence 2015). Haven et al. (2019) report from their survey and focus group that "Biomedical researchers and social science researchers were primarily concerned with sloppy science and insufficient supervision. Natural sciences and humanities researchers discussed sloppy reviewing and theft of ideas by reviewers, a form of plagiarism" (Abstract, Results).

The mainstream peer review systems in scientific and scholarly communication typically operate anonymously (Kriegeskorte 2012). This established, blind peer review model for journals has been criticized as being a flawed process (Smith 2006) or a broken system (Belluz et al. 2016). Peer review bias and unfairness exist to varying degrees in different disciplines (Lee et al. 2013; Rath and Wang 2017). Is there a way to restore the trust in peer review for scientific and scholarly publishing? Pioneers and innovators believe that transparency is the key (Fennell et al. 2017).

OPR initiatives and practices

A small number of pioneering journals have been offering forms of OPR since the turn of the century. Launched in 2001, the journal *Atmospheric Chemistry and Physics*, was among the first OA OPR journals (Pöschl and Koop 2008), along with 36 journals published by BioMed Central (https://www.biomedcentral.com/journals-a-z).

More than 10 years ago, *Nature* conducted a four-month trial of a hybrid model in which the manuscripts underwent formal closed review by referees and were posted to a preprint site for open review by community readers. The exploratory results showed limited use in improving the process. (Opening up peer review 2007). In January 2016, *Nature Communications* started a new OPR trial where the authors could decide on a blind or open review model at submission time and have their review reports published upon the acceptance of the manuscript while the reviewers could decide if they would remain anonymous or sign the review reports (Nature 2015). One year into the trial, 60% of the 787 published papers had open reports (Nature 2016). Four years later, Nature announced that it would add eight Nature Research journals to the trial project beginning in February 2020. The announcement reports that in 2018, 70% of the trial journal articles published open reports; 98% of the authors who published their reviewer reports responded they would do so again. Over the four years, 80% of papers had at least one referee named, which seemed to corroborate the results of a 2017 survey of *Nature* referees: the majority favored experimenting with alternative and more transparent models (Nature 2020).

F1000 beta-tested an open research platform as *F1000Research* in 2012. Articles submitted to *F1000Research* are published within 6–14 days and followed by a totally transparent peer review process during which a reviewer's recommendation and report are published alongside the article. The process was not moderated by an editor. A key difference between post-publication OPR is that *F1000Research* does not make decisions on acceptance or rejection. Instead, it adopts the algorithm for indexing based on the review results: a minimum of 2 approved or 1 approved plus 2 approved with reservations by reviewers. Another distinct feature is that the review process is totally transparent and open in real-time with both open identities and open reports (https://f1000research.com/for-referees/guidelines).

Choosing a middle ground, *PeerJ* launched a new optional OPR journal in 2013; as of this writing, 80% of authors have chosen open reports, and 40% of reviewers have signed review reports (https://peerj.com/benefits/review-history-and-peer-review/). Adopting a similar model, the publisher MDPI first announced optional post-publication OPR in 2014 by the journal *Life* and by 2018 all journals adopted optional OPR. Rittman (2018) reports that 23% of MDPI journal papers published at least one review with open identities. The percentage of the 14 early OPR MDPI journals with open reports include *Publications*

(60%), *Dentistry* (52%), *Medical Sciences* (51%), *Quantum Beam Science* (48%), *Life* (46%), *Brain Sciences* (44%), *J* (43%), *Behavioral Sciences* (41%), *Economies* (40%), *Cosmetics* (39%), *Administrative Sciences* (38%), *Condensed Matter* (37%), *Animals* (34%) and *Atoms* (33%). EMBO Press reports that currently, 95% of their authors chose to publish review reports alongside their papers (EMBO Press 2020).

Another option for open reports, in addition to appearing alongside the article (e.g., *PeerJ*) or in a stand-alone volume (e.g., Elsevier), is for reviewers to deposit their review reports to a research partnership service such as Publons.com. Here the decision to publish reports is made by the reviewers rather than the authors or publishers, given that Publons was created to credit reviewers and authenticate their claims. Recently, Wiley partnered with Publons for their OPR initiatives with 40 participating journals (Wiley2018). Wiley's prestigious journal *Clinical Genetics* was the pioneering journal for this initiative (Graf 2019). As of March 2020, Wiley added 10 titles in early 2020 to expand this initiative (Moylan 2020).

OPR research

As an innovation in peer review, OPR pursues transparency and openness to improve the process (Wang et al. 2016a, b). Transparency in peer review was rigorously studied by researchers for the journal *BMJ* in the 1990s before the first journals implemented OPR. These early research examples that studied the effect of making reviewer identities known to authors or posting reviewer names with the paper concluded that these practices had no effect on the quality of the reviews (Godlee et al. 1998; van Rooyen et al. 1999). Walsh et al. (2000) conducted a controlled trial in *British Journal of Psychiatry* to investigate whether open peer review was feasible. Of the 322 reviewers, 245 (76%) agreed to sign their reviews. A total of 408 unsolicited manuscripts of original research were randomly assigned to the two groups of reviewers. To evaluate the reviews, a seven-item instrument was used to compare the quality of the reviews: importance of research question, originality, methodology, presentation, constructiveness of comments, substantiation of comments, and interpretation of results; in addition, the tone of the review was rated. With cautious notes, the researchers reported that the signed reviews were more courteous and of higher quality than unsigned reviews. Bornmann et al. (2012) compared the reviewer comments of a closed peer review journal and an open peer review journal. They found that the reviewer comments in the open review journal were significantly longer than the reviewer comments in the closed review journal.

Since then, a few studies have investigated author and reviewer attitudes towards OPR, characteristics of open reviews and methods of OPR adoption by existing and new journals. In 2012, Elsevier began a pilot OPR project of selected trial journals (Mehmani and van Rossum 2015). A survey of editors, authors, and reviewers of the five participating trial journals was conducted in 2015 to assess the impact of open review (Mehmani 2016). Forty-five percent of the reviewers revealed their identities. The majority of the reviewers (95%) commented that publishing review reports had no influence on their recommendations. Furthermore, 33% of the editors identified overall improvement in the review quality, and 70% of these editors said that the open review reports were more in-depth and constructive. Only a small proportion of the authors indicated that they would prefer not to publish in open review journals. Mehmani reported high usage of review reports by counting the clicks to the review reports, which indicated the value of open review to the readers.

At a webinar sponsored by Elsevier to discuss how to improve transparency in peer review, Agha (2017) reported on the experience of two Elsevier pilot OPR journals (*International Journal of Surgery* and *Annals of Medicine and Surgery*) that published peer reviewer reports as supplemental volumes. He concluded: “60% of the authors like it or like it a lot and 35% are more likely to publish because of it.” Bravo et al. (2019) observed and analyzed Elsevier’s pilot project of five OPR journals from 2015 to 2017. In order to compare referee behavior before and after OPR, the dataset included 9220 submissions and 18,525 reviews from 2010 to 2017. They found “that publishing reviewer reports did not significantly compromise referees’ willingness to review, recommendations, or turn-around time. Younger and non-academic scholars were more willing to accept invitations to review and provided more positive and objective recommendations. Male referees tended to write more constructive reports during the pilot. Only 8.1% of referees agreed to reveal their identity in the published report.” (Abstract). The authors also published review reports alongside their paper. Wang et al. (2016a, b) analyzed the optional OPR journal *PeerJ*’s publicly available reports for the first three years of the journal (2013–2016). They found that the majority of the papers (74%) published during this time period had open reports; 43% of which had open identities.

If transparency in peer review is the key to tackling the various issues facing the current peer review system, will authors and reviewers embrace OPR? Several large-scale surveys have collected data on attitudes towards OPR with diverse findings. Mulligan et al. (2013) found that only 20% of respondents were in favor of making the identity of the reviewers known to authors of the reviewed manuscripts; 25% of respondents were in favor of publishing signed review reports. In 2016, the OpenAIRE consortium conducted a survey of OPR perceptions and attitudes by inviting respondent participation through social media, distribution lists and publishers’ newsletters. Of the valid 3062 responses, 76% of respondents reported having taken part in an OPR process as an author, reviewer or editor. The survey results show that the respondents are more willing to support open reports (59%) than open identities (31%). The majority of the respondents (74%) believe that reviewers should be given the option to make their identities open. (Ross-Hellauer et al. 2017) Another survey of European researchers conducted by the European Union’s OpenUP Project in 2017 received 976 valid responses. The results of this survey also show that respondents support open reports (39%) more than open identities (29%). This survey also reports a gender difference in supporting open identities (i.e., 35% of female researchers versus 26% of male researchers) (Görögh et al. 2019).

A recent survey by ASAPbio (2018) asked authors and reviewers in the life sciences about their perspectives on OPR. Of the 358 authors, the majority were comfortable (20.67%) or very comfortable (51.96%) with publishing their recent paper’s peer reviews with referees’ names; when asked about the same reviews to be published without referees’ names, the number dropped but still represented the majority: 19.56% were comfortable and 37.71% were very comfortable. Of the 291 reviewers, the majority would be comfortable (32.30%) or very comfortable (40.21%) with posting their last peer review anonymously given the opportunity to remove or redact appraisals or judgments of importance; regarding signing the same review, 28.15% of respondents were comfortable and 32.30% were very comfortable. These results suggest that the majority of the authors are willing to publish their papers’ review reports, with a preference for signed reviews; the majority of the reviewers are willing to have their review reports published without sensitive information, with a preference for anonymity.

The analysis of nearly 2600 responses to Wiley's 2019 Open Research Survey indicates that the respondents' preferred peer review models are double-blind (79%), transparent (44%), and single-blind (34%). Twenty-eight percent of the respondents were not aware of the transparent review model (Moylan 2019).

OPR conceptualization and implementation

Despite the growing interest in OPR, there still is no uniform definition of OPR or generally agreed upon best implementation model. Ford (2013) reviewed the literature on the topic to define and characterize OPR. Acknowledging the diverse views of OPR, she states "the process incorporates disclosure of authors' and reviewers' identities at some point during an article's review and publication" (p. 314). She further characterized OPR by *openness* (i.e., signed review, disclosed review, editor-mediated review, transparent review, and crowd-sourced/public review), and *timing* (pre-publication, synchronous, and post-publication).

Ross-Hellauer (2017) conducted a systematic literature review and identified seven elements based on 22 definitions of OPR. Of the seven elements, *open identities* and *open reports* are considered core elements to recognize OPR journals. The other five elements in the order of frequency of occurrences include *open participation*, *open interaction*, *open pre-review manuscripts*, *open final-version commenting*, and *open platforms/decoupled review*. These elements formed a framework for two surveys conducted by OpenAIRE (Ross-Hellauer et al. 2017) and OpenUP (Görögh et al. 2019). Similarly, Tennant et al. (2017) provided a comprehensive review of journals' peer review practices from the past to the present, which they published in the OPR journal *F1000Research*. Taking a much broader perspective, they examined the pros and cons of open reviews, including public commentary and staged publishing.

Fresco-Santalla and Hernandez-Perez (2014) illustrated how OPR has been manifested by different journals: open reviews (for all or specific papers), signed reviews (obligatory, pre- or post-publication), readership access to review reports (required or optional) and readership comments (pre- or post- publication). Wang and Tahamtan (2017) identified 155 OPR journals, of which the majority were in medicine and related fields. They also found the various characteristics in the implementations by the OPR journals. According to Tattersall (2015), there were ten leading OPR platforms.

Method

This research focuses on the two core elements of OPR journals that Ross-Hellauer (2017) identified: (1) open identities, where reviewer names were made public; (2) open reports, where the original reviews or integrated reviews were publicly available. In addition, we considered when a journal adopted OPR, the journal's discipline coverage, and its publisher. For included OPR journals, authors' rebuttals were not considered in this study, nor were open comments from registered or unregistered readers. This study did not include journals that implemented only one of the following OPR elements in Ross-Hellauer (2017): open participation, open interaction, open pre-review manuscripts, open final-version commenting and open platforms/decoupled review.

Data collection

Although a few journal directory sources attempt to identify OPR (e.g., Directory of Open Access Journals and Transpose), there is no established standard to describe aspects of OPR systematically. Journal records are submitted by users, and the schemas are open for interpretation. To identify relevant OPR journals, we used multiple search strategies and tracked different sources. The Directory of Open Access Journals (DOAJ) indexes more than 14.5 thousand journals and nearly 4.8 million articles. From the results of the advanced search for journals with the filter set to “open peer review,” we retrieved 133 OPR journals. Some DOAJ entries for journals were blogs rather than venues for the publication of research and were thus excluded. Each of the journals was accessed to verify if it publishes open identities or open reports; those misclassified were removed from the dataset. Several websites about peer review and scientific publishing were periodically scanned to keep current on the OPR development: ASAPbio (Accelerating Science and Publication in biology); the International Congress on Peer Review and Scientific Publication; Peer Review Week. Transpose, a database of journal policies on peer review and preprinting (https://transpose-publishing.github.io/#/), was a particularly rich source for identifying candidate journals but many records were not verified by the publishers or editors, and many duplicated or erroneous records had to be corrected by checking the original journals.

Data verification and cleaning

This study used two criteria to select OPR journals, *open identities* and *open reports*; at least one of the two core elements had to be implemented to qualify as an OPR journal. Data from different sources needed to be transformed and verified. As of 23 November 2019, the Transpose database listed 294 OPR journals that adopted open identities and 232 OPR journals that publish open reports, many of which were misclassified perhaps due to the crowdsourcing nature of the database and the record contributors’ ability to distinguish OA from OPR. Unexpectedly, the publisher field was another confusing concept. For example, the newly launched journal *Geochronology* listed the European Geosciences Union (EGU) as the publisher while the journal’s Website had Copernicus Publications as the publisher. Therefore, each OPR journal’s website was visited to verify the data. Some journals (e.g., several journals published by Copernicus Publications and journals by Kowsar) indicated in their editorial policies that they follow OPR. To identify which year the journal started or transitioned to OPR, we accessed issues of the journals to find open reports or open identities in the published articles. If none of the articles published review reports or reviewer identities as of December 2019, the journal was excluded. Further efforts were made to search Websites of the publishers of known OPR journals to identify additional OPR journals that were not indexed in DOAJ or Transpose. For example, Transpose had listed 10 OPR journals for Wiley, but Wiley’s Website news pointed to an excel file of 40 OPR trial journals. We also searched newsletters and lists related to peer review, from which we identified OPR adoption, for example, from *PLOS* in 2019.

Identification of the year a journal began OPR could be a difficult and time-consuming task if a journal did not provide the precise date it adopted OPR. In these cases, we manually checked each issue to find the earliest OPR article. If a journal publisher clearly posted

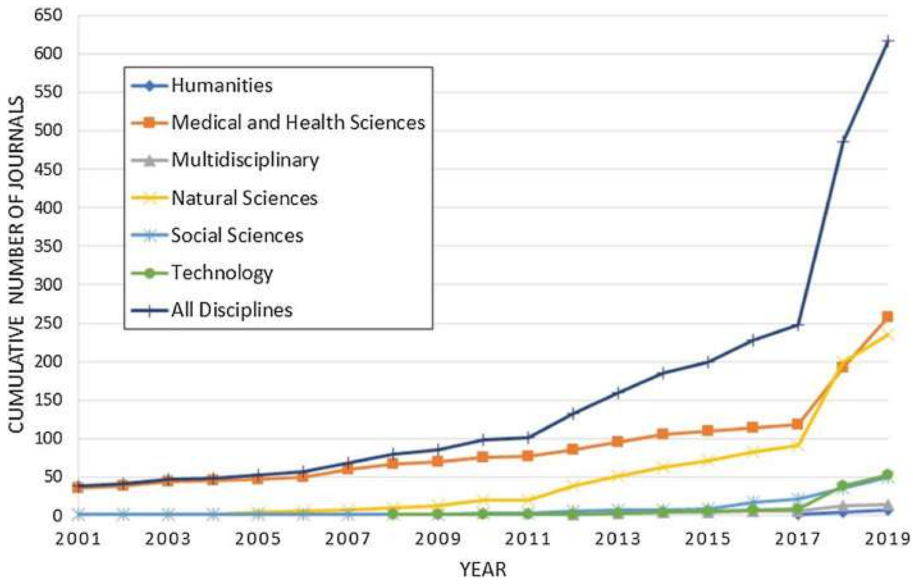

Fig. 1 Growth of OPR journals by discipline groups

information about when OPR was adopted on their editorial or peer review policy page, we used that year (e.g., Kowsar and Wiley).

In this paper, we updated the dataset reported in Wolfram et al. (2019), which was collected in 2018 and consisted of 20 publishers and 174 OPR journals. The final dataset for this expanded study includes 38 publishers and 617 OPR journals as of December 2019. Data were stored in an Excel spreadsheet and were analyzed using cross-tabulations, queries, and qualitative assessment of relevant journal content. Stored information included: journal metadata, year of first OPR use, publisher (name and country of headquarters), policy for reviewer identity, policy for report availability, and high-level journal discipline.

Results

Descriptive data

The growth of OPR adoption—measured either by existing or new journals—is summarized in Fig. 1 by broad discipline. The journals were classified into six broad topical areas using a modified form of the DOAJ classification scheme to determine which disciplinary areas have adopted OPR. Most journals did not report when they adopted OPR or if they have always used OPR. First OPR usage was confirmed by searching early issues of the journals to identify when OPR practices began. In many cases, OPR adoption coincided with the first journal issue.

The early adopters of OPR can be traced back to the beginning of the 2000s. The journals *Atmospheric Chemistry and Physics* and *European Cells & Materials* each implemented a different OPR model, although both launched their first issues in 2001. Similarly, 36 OPR journals published by BioMed Central implemented another model in the same

Table 1 Adoption of OPR by discipline group over time

Discipline group	Year of first OPR journal	# of OPR journals in first year	Total	Percentage of all OPR journals (%)
Medical & health sciences	2001	36	258	41.8
Natural sciences	2001	1	235	38.1
Social sciences	2001	1	50	8.1
Technology	2008	1	53	8.6
Multidisciplinary	2012	2	14	2.3
Humanities	2017	1	7	1.1
Total			617	100.0

Table 2 Adoption of OPR by publishers

Publisher	OPR journals	Percentage of OPR journals (%)	Headquarters location
MDPI	204	33.0	Switzerland
SDI	111	18.0	India
BioMed central	70	11.3	United Kingdom
Frontiers media S.A	64	10.4	Switzerland
Kowsar	51	8.3	The Netherlands
Wiley	40	6.5	USA
Copernicus publications	21	3.4	Germany
PLOS	7	1.1	USA
Elsevier	7	1.1	The Netherlands
EMBO press	5	0.8	Germany
Other publishers	37	6.0	11 countries*
Total	617	100.0	

*United Kingdom (19 journals), United States (9), Argentina (1), Bulgaria (1), Canada (1), France (1), Germany (1), Ireland (1), Kenya (1), The Netherlands (1), Switzerland (1)

year. Since then, there has been steady growth in the number of journals that have adopted OPR, most noticeably in the Medical and Health Sciences, and more recently, in the Natural Sciences over the past 10 years. This growth has increased dramatically since 2017, in which time the total number of OPR journals has more than doubled. The disciplinary distribution of OPR journals appears in Table 1. For each discipline group, its first OPR year and number of articles suggest how OPR is being adopted. Medical and Health Sciences had the most early adopters.

A summary of the most prolific publishers contributing to OPR and their headquarters' country appears in Table 2. Although many journals today attract an international audience and are managed by international teams of researchers, the prevalence of OPR journals associated with publishers based in Europe stands out. Twenty-four of the 38 (63.2%) identified publishers are based in Europe and account for 445 out of the 617 titles (72.1%).

Table 3 Adoption of open reports by discipline

Discipline	Mandated	Optional by author	Optional by editor	No open reports	Total
Medical and health sciences	165 (64.0%)	63 (24.4%)		30 (11.6%)	258
Multidisciplinary	7 (50.0%)	7 (50.0%)			14
Natural sciences	86 (36.6%)	111 (47.2%)	2 (0.9%)	36 (15.3%)	235
Social sciences	12 (24.0%)	30 (60.0%)		8 (16.0%)	50
Humanities	1 (14.3%)	5 (71.4%)		1 (14.3%)	7
Technology	3 (5.7%)	44 (83.0%)		6 (11.3%)	53
Total	274 (44.4%)	260 (42.1%)	2 (0.3%)	81 (13.1%)	617

Table 4 Adoption of open identities by discipline

Discipline	Mandated	Optional by reviewer	Anonymous	Total
Medical and health sciences	146 (56.6%)	111 (43.0%)	1 (0.4%)	258
Multidisciplinary	7 (50.0%)	7 (50.0%)		14
Natural sciences	88 (37.4%)	139 (59.1%)	8 (3.4%)	235
Social sciences	17 (34.0%)	33 (66.0%)		50
Humanities	2 (28.6%)	5 (71.4%)		7
Technology	8 (15.1%)	45 (84.9%)		53
Total	268 (43.4%)	340 (55.1%)	9 (1.5%)	617

Although the publishers are based in Europe, many of the journals they publish may support journals originating from other areas of the world (e.g., Kowsar). Furthermore, 500 of the OPR journals (81.0%) are published by only five publishers (MDPI, SDI, BioMed Central, Frontiers Media S.A., Kowsar). This points to the important role that publishers have played to date in the promotion of OPR.

OPR transparency in current practice

A fundamental principle of OPR is transparency. This includes open identities and/or open reports. Publishers and editors of journals adopted different levels of transparency,

Table 5 Who decides about open identities and open reports

Open reports	Open identities			
	Decided by reviewer	Mandated	Anonymous	Total
Decided by Author	260	0	0	260
Decided by Editor	1	0	1	2
Mandated	77	189	8	274
Not Available	2	79	Blind review	81
Total	340	268	9	617

where one or both of the transparency elements may be optional or required (e.g., EMBO Press 2020). Table 3 reports the adoption of open reports based on the broad discipline of the journals. The percentage of mandatory open reports is highest in the Medical and Health Sciences (64.0%), and second highest in the Multidisciplinary category (50.0%). Mandatory open reports are much lower for Humanities (14.3%) and Technology (5.7%), where optional open reports are more common. The availability of mandated or optional open identities was much more common across all disciplines, with only 9 journals (8 from the Natural Sciences and 1 from Medical and Health Sciences) requiring anonymity. Summary data for open identity adoption by discipline appear in Table 4.

Open identities may be mandated, optional (decided by the reviewer) or anonymous. Similarly, open reports may be mandated, optional (decided by the author or editor), or not available. The frequency of each combination appears in Table 5. When reviewers remain anonymous and their reports are not made available, this is traditional blind peer review (the lower right cell). The vast majority of OPR journals (608 or 98.5%) either require reviewers to identify themselves (268 or 43.4%) or allow reviewers to choose whether to identify themselves (340 or 55.1%). Similarly, 536 (86.9%) of the journals either require reports to be open (274 or 44.4%) or allow authors or editors to choose whether to make the reports open (259 or 42.3%). Only 189 (30.6%) journals require both open identities and open reports.

Transparency of the emerging OPR implementation approaches

The current OPR landscape is complex and exhibits a variety of configurations ranging from opening some aspects of the established blind-review process to a fully transparent process. Although there is no simple way to define the emerging OPR practices, a descriptive framework focusing on how *open identities* and *open reports* are being fulfilled during the review process and what end products are available for open access are depicted in Fig. 2.

At the implementation level, an OPR journal needs to decide:

1. *Who* makes decisions: reviewer, author, and editor/journal;
2. *When* the decision is made for a specific core element: pre-, post, or concurrent process;

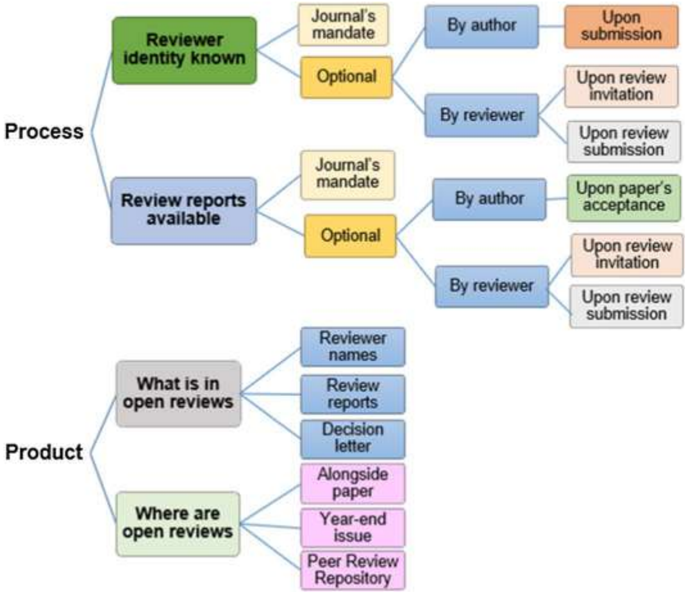

Fig. 2 Process–product approaches

3. *What* is contained in open reports: original reports, a consolidated letter, or invited commentaries by reviewers who made significant contributions to the paper's revision;
4. *Where* the open reports can be accessed.

These four factors can potentially define the level of transparency which a journal puts into practice for OPR. For example, *F1000Research* is the most transparent OPR journal because its peer review process is totally open; both referee identity and review comments are instantly accessible alongside the manuscript while it is being reviewed and revised. As a contrast, the OPR journals published by Frontiers only publish each paper with its reviewers' names, which is a minimum level of open identity. The process and the main product are still very much closed to the readers for whom the articles are published.

The emerging models varied in terms of transparency. Figure 3 shows four representative implementations:

1. Frontiers' OPR journals publish only referee identities alongside articles without open reports as an open identities-only model;
2. *PeerJ* provides optional open identities to referees and optional open reports to authors, representing a range of journals adopting this model;
3. BMC's OPR journals publish both open identities and open reports alongside articles;
4. *F1000Research*, the first of its kind, makes the review process itself open in addition to open identities and open reports. *F1000Research*, as post-publication OPR, has no acceptance or rejection decision to be made as a result of peer review, but an article will not be indexed in any bibliographic databases without passing the threshold within a defined timeframe consisting of two approved (✓✓) or one approved (✓) plus two approved with reservations (??).

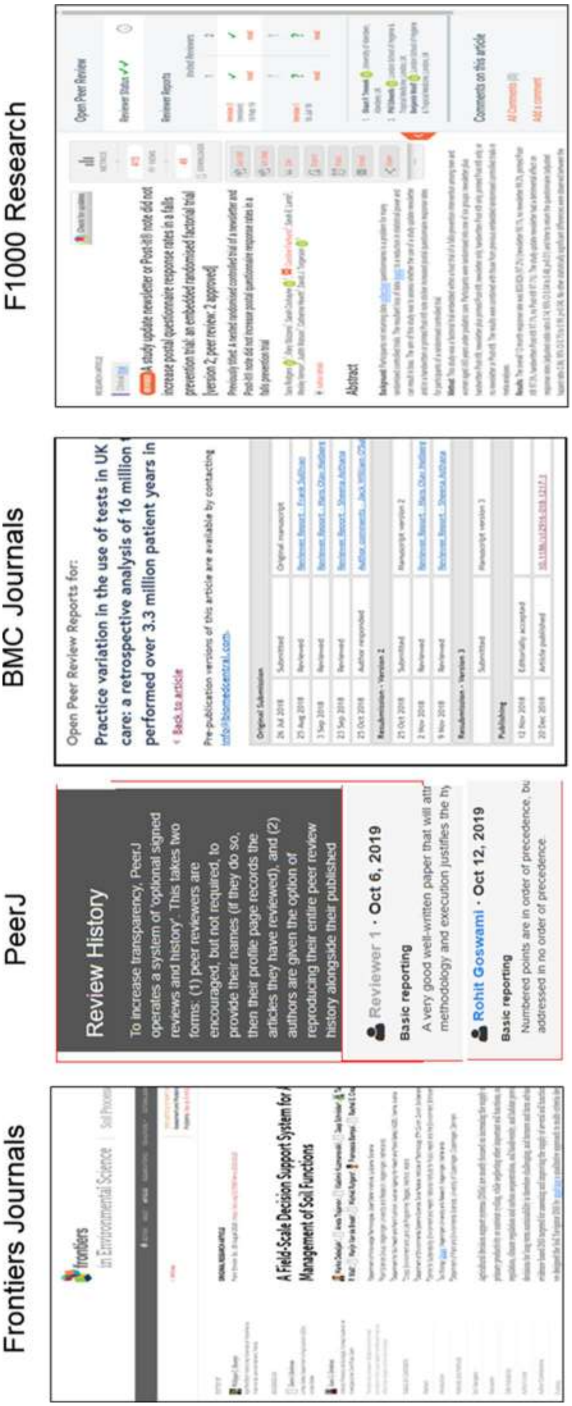

Fig. 3 OPR models as implemented by publishers

Discussion

This study represents the first comprehensive investigation of the scope and depth of OPR adoption in the open science era. Since the *BMJ* experiments with open reviews more than 20 years ago, the adoption of OPR has gone from 38 journals in 2001 to at least 617 journals by the end of 2019. Figure 1 demonstrates that there has been steady growth in the number of OPR journals over time, led by journals in Medical and Health Sciences and the Natural Sciences, but with much higher growth since 2017. This growth has been prompted by a small number of publishers. The remaining disciplines have been much slower and later to adopt OPR. The Humanities have different scholarship cultures as compared to the Natural Sciences and have been slow in adopting open access overall (Eve 2017; Gross and Ryan 2015).

Several publishers have served as pioneers and early promoters of OPR. The five publishers of the most OPR journals that have led the way—MDPI, SDI, BioMed Central, Frontiers Media S.A. and Kowsar–have adopted different implementations of OPR. BioMed Central, as one of the earliest OPR journal publishers in this study, and SDI require both open reports and open identities. Kowsar requires open reports but makes referee identities optional. MDPI makes open reports and open identities optional for authors and reviewers, respectively. Frontiers Media S.A. requires open identities but does not provide open reports for its OPR journals.

More than 60% of the publishers in this study, who publish more than 70% of the OPR journals identified, are based in Europe, signifying Europe's leading role in the OPR movement. This strong European effort is also seen in the larger open science movement, where organizations such as OpenAIRE and OpenUP are investigating all aspects of this movement, including OPR. Eleven of the identified publishers are based in the United States, indicating that there is also a growing interest in adopting OPR outside of Europe. Publishers based in other countries than those of the more prolific publishers have been slower to adopt forms of OPR as evidenced from the singular representation by these nations.

Multiple OPR practices emerge from the analysis of the data that show different levels of transparency in implementation. The level of transparency can be characterized along a continuum. The most transparent model is the concurrent open review process exemplified by *F1000Research*, where reviewers' identities and reports are instantly available alongside manuscripts and are published upon submission following initial format checking. Another model that promotes total transparency, exemplified by many BioMed Central journals, provides access to the complete report history and author exchanges as well as open identities alongside the published articles, after acceptance. The next several implementations that allow authors and/or reviewers to participate in open review decisions during the process include: mandated open reports but optional open identities (e.g., Kowsar journals), mandated open reports without open identities (e.g., the journal *Ledger*), and optional open reports with optional open identities (e.g., *PeerJ*). The most limited implementation, used by the Frontiers Media S.A. journals, is a closed review process with the published articles including only the names of the reviewers.

Two recommendations arise from the findings:

1) Publishers should make their OPR information (policies, open reports, open identities) more accessible and should more prominently display their OPR status and adoption. This information was sometimes buried and difficult to locate.

2) A repository or registry of OPR journals that provides key elements relevant to OPR is needed. Information contained in sources such as DOAJ and Transpose is limited and frequently incorrect.

Conclusion

The adoption of the OPR innovation is growing. This growth has been largely spurred by a small number of publishers, primarily based in Europe. To date, OPR has been adopted mostly by journals in the Medical and Health Sciences and the Natural Sciences. However, the number of OPR journals remains a very small percentage of scholarly journals, overall. The fact that there are multiple approaches to the adoption of OPR indicates there is no consensus at present regarding best practices. The highest level of OPR transparency includes open identities along with open reports, but only a minority of the OPR journals identified have adopted complete transparency.

Limitations of the present research must be recognized. Currently, there is no universal way to identify journals that adopt OPR. Our approach was to cast a broad net using multiple sources to identify candidate OPR journals, which is time-consuming and often hit-or-miss. It is possible that we have missed OPR journals that are not indexed by the databases searched or by the publishers already in our dataset despite the fact that we expanded our searches to the OPR publishers to ensure inclusion. Similarly, given the growth in the number of OPR journals over the past couple of years, the findings presented here represent a snapshot as of late 2019. The OPR landscape is changing quickly. Like any indexing source, there may also be a regional or language bias, where there are additional examples of OPR journals that may not be evident due to a lack of familiarity with the publication language. Although most publishers post annual reports with metric data including the number of articles, citation counts, Journal Impact Factor, rejection rate, etc., they lack annual OPR metric data on the number or percentage of articles with optional open reports and open identities; both are essential metric data to document OPR adoption.

The next phase of this research is examining open report contents using text mining approaches to determine if there are quantitative and qualitative differences in the open reviews based on the OPR approaches used. A scoring instrument is being developed and tested to measure different models.

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Data availability A csv file of the journal data can be found at: https://doi.org/10.5281/zenodo.3737197.

Compliance with ethical standards

Conflicts of interest All authors declare that they have no conflict of interest.

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Gambling researchers' use and views of open science principles and practices: a brief report

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ABSTRACT
Scientists across disciplines have begun to implement 'open science' principles and practices, which are designed to enhance the quality, transparency, and replicability of scientific research. Yet, studies examining the use of open science practices in social science fields such as psychology and economics show that awareness and use of such practices often is low. In gambling studies research, no studies to date have empirically investigated knowledge of and use of open science practices. In the present study, we collected survey data about awareness and use of open science practices from 86 gambling studies research stakeholders who had attended a major international gambling studies conference in May 2019. We found that – as hypothesized – a minority of gambling research stakeholders reported: 1) either some or extensive experience using open science research practices in general, and 2) either some or regular experience using specific open science practices, including study pre-registration, open materials/code, open data, and pre-print archiving. Most respondents indicated that replication was important for all studies in gambling research, and that genetic, neuroscience, and lab-based game characteristic studies were areas most in need of replication. Our results have important implications for open science education initiatives and for contemporary research methodology in gambling studies.

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Gambling; research design; reliability; best practice; survey

Introduction

Efforts to promote open science have advocated for greater endorsement of open science principles related to research development, reporting, and access among gambling researchers (e.g. Blaszczynski & Gainsbury, 2019; Louderback et al., 2021). Such principles suggest that (1) research development should be transparent; (2) research reporting should be complete, and not dependent upon outcomes; and (3) research access should be open. Practices that support these principles include, but are not limited to, use of research pre-registration and registered reports (i.e. public documentation of, or peer review of, research methods and analytic plans prior to commencing a study) for

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transparency of development, clear separation of prespecified and *ad hoc* analyses for completeness of reporting, and freely available materials, studies, and data (i.e. unrestricted availability of research components and products) for research access (see Nosek et al., 2015). Recent efforts to make open science more widespread are in response to observations of questionable research practices (e.g. *p*-hacking, or use of analytic approaches to produce a preferred *p*-value, and HARKing, or *h*ypothesizing *a*fter *r*esults are *k*nown; Bishop, 2019; Kerr, 1998; Wicherts et al., 2016) and poor research replicability in the published behavioral research literature (see Open Science Collaboration, 2015; also see Klein et al., 2018). Notably, recent research suggests that rigorous adoption of open science principles and practices is associated with high replicability in novel behavioral research (Protzko et al., 2020), suggesting that increased adoption of such approaches might hold the potential to favorably impact the gambling studies research literature.

Research about open science beliefs and practices

Open science only recently has begun to gain widespread interest in the scientific community (Banks et al., 2019). Studies documenting researchers' beliefs and practices related to open science tend to report limited experience, but growing interest in practices such as data sharing (e.g. Abele-Brehm et al., 2019; Houtkoop et al., 2018), open peer review (e.g. Ross-Hellauer et al., 2017), and open access publication and paper repositories (Creaser et al., 2010; Rodriguez, 2014; Rowley et al., 2017; Xia, 2010), among others. Additional studies have examined facets of open science in practice, for example, showing that adherence to pre-registrations is typically not perfect (Claesen et al., 2019) and that liberal researcher degrees of freedom (i.e. methodological flexibility inherent in research design or analytic plans; Wicherts et al., 2016) remain common in pre-registered studies (Veldkamp et al., 2017). However, to date, there have been no studies of gambling researchers' understanding or use of open science principles and practices.

Open science beliefs and practices among gambling researchers

The gambling studies field is not entirely absent of open science practices. For example, during 2009, the Division on Addiction at Cambridge Health Alliance, with funds from the online gambling operator *bwin.party*, created an open data archive, The Transparency Project (Shaffer et al., 2009). Upon its creation, the Division on Addiction used The Transparency Project to share its industry-funded player data research datasets and improve the transparency of its works. This early instance of open science facilitated scientific progress – allowing independent researchers to publish empirical research on gambling that they otherwise could not (e.g. Brosowski et al., 2012; Coussement & De Bock, 2013; Percy et al., 2016). However, this effort did not stimulate widespread discussion of open science principles and practices among gambling researchers. In fact, despite a growing recent awareness of and literature pertaining to issues including research replication (Klein et al., 2018), scientific transparency (McNutt, 2016), and the need to embrace open science (Frankenhuis & Nettle, 2018; Munafò et al., 2017; Nosek et al., 2015; Open Science Collaboration, 2015), additional published discussion of the need for scientific self-reflection and adoption of open science tactics among gambling researchers did not occur until about a decade later (Blaszczynski & Gainsbury, 2019; Heirene, 2020; Heirene & Gainsbury, 2020; LaPlante, 2019, 2020; LaPlante & Gray, 2019; Louderback et al., 2021; Wohl et al., 2019).

Within this context, understanding how well gambling researchers understand open science practices and their value to the research process can provide insight into gaps between actual and ideal research practices in this field. To gain a preliminary understanding of how well open science is integrated into gambling research, we collected primary data from a convenience sample of gambling research stakeholders who presented or coauthored presentations at a major international conference on gambling research during 2019 with a survey that measured experience with open science and related practices.

The present study

The present study was primarily descriptive and includes some exploratory comparisons; however, because academic discussion of open science practices is limited among gambling research stakeholders, we hypothesized that:

H1: *A minority of respondents will endorse that they have some or extensive experience with open science principles, generally.*

H2: *A minority of respondents will endorse that they have some or regular experience with specific types of open science practices.*

H3: *A minority of respondents will endorse that the concept of replicability is relevant to all gambling studies.*

Methods

We pre-registered our study protocol on the Open Science Framework (https://osf.io/xq2b6). The Cambridge Health Alliance Institutional Review Board reviewed and approved this study (exemption granted, 45 CFR 46.104(d)(Category 2(i)).

Participants

Our initial list of participants included all possible gambling conference registrants who presented or coauthored presentations at the 17th International Gambling and Risk Taking Conference that took place in Las Vegas, Nevada, USA during May 2019 (N = 331). This conference markets itself as the largest in the field of gambling studies and includes both U.S.-based and international scholars, researchers and other gambling stakeholders (University of Nevada, Las Vegas, 2019). The presenter population from which we sampled was diverse in academic interests; the conference hosted presentations across multiple disciplines related to gambling, such as history, business, social sciences, and mathematics (Digital Scholarship at UNLV [DSUNLV], 2019). Because this study primarily was exploratory, we did not complete a power analysis, but instead sought to enroll all possible of these registrants. Upon obtaining the list of potential survey recipients and removing invalid e-mail addresses as well as e-mail addresses for authors of the present study, we distributed the survey invitation, consent form, and survey using Qualtrics to 315 potential respondents beginning 30 April 2020. We also used the Qualtrics survey system to send three reminder e-mails, one per week after the initial e-mail invitation. We stopped collecting data on 29 May 2020, one week after sending out the final reminder e-mail. We did not reimburse respondents for their participation. Of the 315 total individuals sampled, 86 people responded to the survey, representing a response rate of 27.3% (86/315 = 0.273).

Measures

Our survey was an adaptation of the Beaudry et al. (2019) Swinburne Open Science Survey (see survey questionnaire on pp. 7–12 in our pre-registration: https://osf.io/xq2b6) and included the following domains: (1) General experience with open science practices; (2) Experience with pre-registration; (3) Concerns with pre-registration; (4) Experience with open materials/code; (5) Concerns with open materials/code; (6) Experience with open data; (7) Concerns with open data; (8) Experience with pre-print archiving; (9) Concerns with pre-print archiving; (10) Feelings about replicability; (11) Areas in gambling studies in need of replication; (12) Job type; (12a) Academic job experience; and, (13) Country of residence.

We also collected data on participants' thoughts and opinions related to open science and gambling studies with two open response questions:

(1) Do you have any other thoughts or opinions about open science principles or practices that you would like to share?
(2) Do you have any other thoughts about the current state of research in the field of gambling studies that you would like to share?

Analytic strategy

We completed descriptive analyses of all survey items. To examine our hypotheses, we recorded whether a minority or a majority reported some or extensive/regular experience with general and specific open science practices. Likewise, for the item that addressed the concept of replicability, we reported whether a minority or a majority reported that the concept of replicability is relevant for all gambling studies.

We used Fisher's exact tests to examine relationships between open science practices and concerns, and the following categories: (1) job type (i.e. primarily academic or primarily non-academic); (2) academic job experience (i.e. developing, early, mid, later, and late career); (3) region of residence (using the United Nations Geoscheme; https://www.emiw.org/fileadmin/emiw/UserActivityDocs/Geograph.Representation/Geographic-Representation-Appendix_1.pdf, i.e. Africa, Americas, Asia, Europe, and Oceania); and (4) research productivity quartile (using the Scimago Institutions Ratings of scientific research productivity by country as of 9/10/2020; quartile 1 represents the most productive countries; https://www.scimagojr.com/countryrank.php?

order=h&ord=desc).[1] We used the standard two-tailed $p < 0.05$ criterion for determining if each test was statistically significant.

To analyze the two open response questions, we created a word frequency cloud for each question using the *wordcloud*() package in R (version 3.6.2). We reported the top 30 most used words that have substantive meaning in each word cloud (i.e. excluding articles including: a, I, and, the, you/your, etc.).

Results

Results related to our assessment of hypotheses are reported here, and a full listing of results is available on our Open Science Framework project page in our online Supplemental Findings document (https://osf.io/qrjnd/).

Experience with open science principles and practices

Table 1 shows that a minority of respondents reported some or extensive experience using open science practices in their own research, confirming Hypothesis 1. Likewise, our examination of specific open science practices indicated that for all practices considered, a minority of respondents reported some or regular experience using a particular practice in their own research. Therefore, Hypothesis 2 also is confirmed.

Concerns with open science principles and practices

In preplanned exploratory analyses, we examined stakeholders' concerns about specific open science practices. Table 2 shows that minorities of respondents endorsed each concern across all practices. Pluralities suggested the following primary concerns: (1) pre-registration: I need to look at my data before I can decide how to best analyze it; (2) open materials/code: There could be issues related to intellectual property; (3) open data: There could be issues related to privacy; and, (4) pre-print archiving: Non-peer reviewed findings might add noise to the literature. Proportions of respondents who indicated they had no concerns ranged from 22.89% for open data to 31.33% for open materials/code.

Importance of replicability

We observed that 51.22% of respondents who provided their opinion (n = 82) suggested that replicability is relevant for all gambling studies. Hypothesis 3 is not confirmed. From greatest to least, proportions of respondents (n = 69) ranked these areas first as most in

Table 1. Percentage of respondents who indicated some or extensive/regular experience with aspects of open science.

Variable (n)	Valid %
I have some or extensive/regular experience with . . .	
Open Science Practices (86)	44.18
Study pre-registration (86)	31.40
Open materials/code (83)	32.53
Open data (83)	48.19
Pre-print archiving (82)	15.86

Table 2. Top three concerns by open science practice.

Variable (*n*)	Valid %
Concerns with study pre-registration (86)	
Need to look at data before deciding how to best analyze it	33.72
Stifles research creativity or flexibility	25.58
Others might take ideas	23.26
Concerns with open materials/code (83)	
Issues related to intellectual property	37.35
Might lose control over materials/code	34.94
Might not receive appropriate credit	24.10
Concerns with open data (83)	
Issues related to privacy	44.58
Others might use my data for another study	33.73
Might lose control over how data are used	32.53
Concerns with pre-print archiving (82)	
Might add noise to the literature	37.80
Journals might not publish findings if there is a pre-print	36.59
Others might copy my ideas & Might reveal differences in pre-print and publication	17.07

This table shows the top three concerns reported for each of the four specific open science practices (i.e. pre-registration, open materials/code, open data, and pre-print archiving) in descending order.

need of replication: (1) genetics (18.84%), (2) lab-based game characteristic studies (15.94%), (3) neuroscience (14.49%), (4) prevalence surveys, public policy impacts, & responsible gambling program evaluations (8.70% each), (5) problem gambling measurement tools (7.25%), (6) socio-economic impact studies (5.80%), (7) responsible gambling tools & other studies (4.35% each), and (8) business research (2.90%).[2]

Bivariate analyses

In preplanned exploratory analyses, we examined relationships between open science practices and concerns and key respondent categorization groupings. First, we examined job type (n = 82). Most respondents reported having an academic-related occupation (74.39%). We observed no differences in five open science experiences by job type. We also observed that for 1 of 34 open science concerns (i.e. concern that open materials/code could violate epistemology; 1 df; $p < 0.05$; $\boldsymbol{\varphi} = 0.24$) there was a statistically discernible effect. Specifically, 5 out of the 21 (23.8%) respondents from non-academic jobs thought this was a concern as compared to only 4 out of 61 (6.6%) academic job respondents.[3] There also was no difference in opinions about the relevance of replicability to gambling studies by job type.

Second, we examined academic job experience. Among those who indicated their academic experience (n = 61), a plurality of respondents (39.34%) indicated that they were 11–30 years post terminal degree. We observed that for 1 of 5 open science experience analyses (i.e. experience with pre-registration; 12 df; $p < 0.05$; $\boldsymbol{V} = 0.34$), there was a statistically discernible effect. Specifically, only one respondent who was in graduate school for a Doctoral degree (11.1% within that category) and one respondent who was 1–10 years post-terminal degree (5.6%) reported *not* being aware of study pre-registration, as compared to 12 people who were 11–30 years post-terminal degree (50.0%) and 3 people who were 31–40 years post-terminal degree (42.9%). Likewise, for 2 of 34 open science concerns (i.e. concern that pre-registration stifles research creativity or flexibility; 4 df; $p < 0.05$; $V = 0.45$; and, concern that pre-prints might allow others to copy one's ideas; 4 df; $p < 0.05$; $V = 0.51$), there was a statistically discernible effect. Specifically, 45.8% of respondents ($n = 11$) who were 11–30 years post-terminal degree thought pre-registration could stifle creativity vs. only 11.1% ($n = 1$) for respondents who were in graduate school for a Doctoral degree and 5.6% ($n = 1$) for respondents who were 1–10 years post-terminal degree. Moreover, 41.7% of respondents ($n = 10$) who were 11–30 years post-terminal degree thought that pre-prints might allow others to copy one's ideas, as compared to no respondents who were in graduate school and no respondents who were 1–10 years post-terminal degree who voiced this concern. There also was no difference in opinions about the relevance of replicability to gambling studies by academic job experience.

Results from the analyses of views of and concerns with open science practices and replicability by region and research productivity, as well as the two word clouds, are reported in the online Supplemental Findings document (https://osf.io/qrjnd/). Importantly, we note that the region and research productivity analyses had very small cell counts for running inferential tests and are reported for sake of completeness, but should be interpreted with caution. The word clouds showed that terms related to transparency occurred frequently ('open', 'sharing', 'available', 'guidelines'), as did terms related to potential limitations ('barriers', 'problem'), and different stakeholder groups ('researchers', 'journals', 'public', 'companies', 'casinos').

Discussion

In this study, we surveyed 86 stakeholders from a major gambling studies conference to better understand the extent to which respondents were aware of open science practices, potential concerns related to open science, and views regarding research replicability. We found that although many respondents were aware of open science in a general sense and some open science practices specifically, only a minority of respondents had used open science practices in their own research. Most gambling researchers viewed replication as important for all studies, suggesting that there is considerable interest in replication for the existing academic literature. Exploratory analyses examining open science experience and open science concerns identified few differences by job type and academic job experience.

Overall, our findings suggest a fairly broad need for open science education among gambling researchers. Specific areas of need include addressing concerns that open science might prevent research flexibility, lead to a loss of credit for important research and research materials, and the possibility of degrading the research literature by circumventing peer-review. Training and practical exposure to open science practices should make clear that tools are available to address many of these concerns already. For example, publishing timestamped 'transparent change' documents alongside research pre-registrations allows researchers to maintain analytic flexibility and innovation in real time (see an example of a transparent change document here: https://osf.io/25xr9/). Likewise, new citation practices for open data can provide new avenues for publicly crediting important research data and associated materials. Finally, preprint servers actually might improve the peer-reviewed literature by providing a clear and open feedback process from a diversity of authors that the existing process currently does not tap.

Implications for gambling studies research

Despite our finding that the majority of respondents thought that replication is important for all gambling studies, there has not yet been a comprehensive examination of the replicability of research findings in this field. This is potentially problematic, because replication rates in gambling studies might mirror those from disciplines such as psychology, which uses similar research methodologies. Such replication rates tend to be alarmingly low. For example, Klein et al. (2018) examined 28 classic and contemporary social psychology effects and found that only 54% of the effects replicated. Recently, a z-curve analysis (Brunner & Schimmack, 2020) indicated evidence of publication bias and an Expected Replication Rate ranging from 0.61 to 0.79 in the gambling product safety literature (McAuliffe et al., 2020).[4] We note that this range is in line with observations from a number of other social sciences. More replication work – including direct replication of published gambling studies – is needed to understand the validity of the published literature.

We also show that the use of open science practices is limited to a minority of respondents in our sample. This rate of participation is similar to other academic disciplines (e.g. in psychology, see Giofrè et al., 2017; in education, see Sampson et al., 2013). Part of this lack of awareness and use of open science practices might be due to limited education in graduate school and among early career professionals on this topic, but much might also relate to the absence of related continuing education opportunities for mid-career researchers. It remains to be determined whether the issues identified as limiting other areas of behavioral science (e.g. poor replication rates), including psychology, economics, marketing and more, also affect gambling studies. However, given the overlap of research methods and theoretical underpinnings, we suggest that open science education, across all topics, should be more widespread among aspiring and established scholars alike (see Banks et al., 2019; Schönbrodt, 2019). Additionally, the unexpected finding that a majority of respondents view replication as important for all types of gambling studies suggests that gambling studies researchers might support a large-scale replication initiative – especially for topics such as genetics, lab-based game characteristic studies, and neuroscience. Such an undertaking would not be easy, but as LaPlante (2019) and Wohl et al. (2019) argue, it is essential that gambling studies evaluate the replicability of its literature because a considerable body of policies rest upon its empirical research findings.

Study limitations

Of course, our study is not without limitations. First, although our sample was based on a population of gambling stakeholders from a major conference, it was still a convenience sample and might not represent the views of all gambling stakeholders. Second, the response rate was middling, so there might be selection bias in the sample. In particular, potential respondents who responded to the survey might be different than those who did not respond to the survey. Third, our population included attendees from only one conference on gambling studies in the United States, so it might not be representative of other populations of gambling researchers such as those who typically attend conferences in Europe, Asia, or other areas. Fourth, we completed the online survey during the COVID-19 pandemic, so our response rate and responses might have been influenced by this major global health crisis. Fifth, our preliminary description of open science practices and opinions relate to the questions we employed, so other constructions (e.g. other response options about areas most in need of replication) might yield a different picture. Sixth, our sample size was small, which likely limited our power to detect statistically significant effects (e.g. for bivariate analyses, which mainly suggested no discernable differences among groups).

Concluding thoughts

Open science provides numerous benefits for the scientific process, including enhancing transparency, researcher independence, objectivity, and scientific rigor. Yet, this approach is relatively new, and much remains to be discovered about how to apply open science principles and practices to all types of research. Gambling studies are diverse, containing multiple disciplines. Some aspects of open science might be easier to apply to some disciplines than others. Facilitating additional empirical research about the use of open science among gambling studies researchers will help the field better understand knowledge gaps for education planning and help identify disciplines that might need open science innovations to engage effectively. Conversely, future work might explore how gambling studies might inform the next generation of open science principles and practices. Nonetheless, by embracing open science principles and practices, gambling studies can reexamine its key findings and potentially experience similar benefits as other fields, advancing reliable findings and moving past those that are not. These benefits are particularly important given the clinical and policy implications of many findings in gambling studies.

Notes

1. Results related to region of residence and research productivity, as well as the two word clouds (see pp. 27–28 in supplement), are available in the online supplement (https://osf.io/qrjnd/).
2. Although we pre-registered the ranked choice question regarding areas most in need of replication, our reporting of these descriptive statistics was unplanned and exploratory; that is, we had no expectations for the descriptive patterns we might observe.
3. Although we did not pre-register an intention to complete Bonferroni adjustments for our bivariate analyses, we note that employing such an adjustment to each family of tests suggests that we no longer observe any statistically significant effects for the bivariate analyses, except for the analysis of region of residence and experience with study pre-registration, and the analysis of research productivity quartile and the concern that others might ask for assistance with open materials/code. However, Bonferroni is a conservative adjustment that might be too severe for exploratory research (Bender & Lange, 2001).
4. The z-curve is a relatively new approach to assessing the replicability of a given field, or 'methods for predicting the success rate if sets of significant results were replicated exactly' (Brunner & Schimmack, 2020, p. 1). In brief, z-curve uses published test statistics from a given field to derive the average power of a set of published studies and estimate statistics

such as the Expected Replication Rate and the Expected Discovery Rate. Interested readers should consult Bartoš and Schimmack (2020) for additional details.

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Data availability statement

The data described in this article are openly available in the Open Science Framework at https://osf.io/7dgnm/.

Open scholarship

This article has earned the Center for Open Science badges for Open Data, Open Materials and Preregistered. The data and materials are openly accessible at https://osf.io/7dgnm/.

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During the past 5 years, Debi A. LaPlante has served as a paid grant reviewer for the National Center for Responsible Gaming (NCRG; now International Center for Responsible Gaming [ICRG]), received travel funds, speaker honoraria, and a scientific achievement award from the ICRG, has received speaker honoraria and travel support from the National Collegiate Athletic Association, received honoraria funds for preparation of a book chapter from Universite Laval, received publication royalty fees from the American Psychological Association, and received course royalty fees from the Harvard Medical School Department of Continuing Education. Dr. LaPlante is a non-paid member of the New Hampshire Council for Responsible Gambling.

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RESEARCH ARTICLE

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Open science for responsible innovation in Australia: understanding the expectations and priorities of scientists and researchers

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ABSTRACT

Recent arguments for responsible innovation to progress beyond the narrow focus on open access and toward open science present the opportunity for a deliberate global transition to a culture of transparent and open scientific conduct that will deliver greater societal benefit. This paper presents results from a survey of 171 Australian scientists, researchers and other professionals on their expectations and perspectives of transparency and openness in current scientific research practice. The results suggest that for this cultural transition to occur, the responsibility for strengthening transparency and openness must be undertaken not only by scientists and researchers, but also research funding and delivery agencies, and even those beyond the research and innovation sector. These findings are a first step towards defining and understanding what open science means in an Australian context, and what shifts are needed from researchers, research institutions and policy makers to move toward open science for responsible innovation.

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Introduction

Globally, there has been a steady move toward open science over recent years. However, institutional commitments to open science have tended to begin with a focus on the more narrowly defined open access to research data, findings and outputs. This has been evidenced by the commitments to open access in the European Commission's Horizon 2020 program (European Commission 2011); a commitment later reaffirmed and expanded by the Commission with the call for 'open innovation, open science and open to the world' (European Commission 2016). Along similar lines, international coalitions between scientists (e.g. OA 2020, established in 2015) and research funders (cOAlition S n.d., established in 2018) have formed to promote open access, whilst a number of countries including France, Denmark and Sweden have begun to develop national open access implementation plans (MESRI 2018; MHES 2018; Swedish Research Council 2015).

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In Australia, there has also been a shift toward establishing a national strategy for open access driven by the Productivity Commission (Productivity Commission 2016), advocacy groups including the Australian Open Access Strategy Group (AOASG), the Council of Australian University Librarians (CAUL), and the Australian Library and Information Association (ALIA); all supported by the recent Excellence in Research Australia report (Australian Research Council 2019). In lieu of a national framework for open access, the Australian Government's major research funders, the Australian Research Council (ARC) and the National Health and Medical Research Council (NHMRC), have open access policies in place (Australian Research Council 2017; National Health and Medical Research Council 2018), as do half of Australia's universities (AOASG and CAUL 2019) and many of Australia's publicly funded research agencies (PFRAs).

Justifications for open access in Australia are many and varied. For some, including the Productivity Commission, open access is expected to improve cost efficiencies in the publication process, as well as enable 'faster and wider dissemination of the knowledge and ideas contained within them' (Productivity Commission 2016, 29). This unlocks the potential for increased benefits associated with open access policies, and seeks to improve research integrity, foster collaboration, and enhance track record and assessment processes that contribute to 'a stronger knowledge economy' (National Health and Medical Research Council 2018, 1). Open access is also anticipated to build public trust and engagement in science, as well as promote greater translation of science into policy (AOASG & CAUL 2019).

Noting the breadth of benefits sought from open access initiatives in Australia, this paper offers a timely and valuable contribution in extending this current focus towards open science. In this paper we seek to return to the underlying principles of transparency and openness so that we might work towards establishing a shared understanding of what open science means for Australian scientists, researchers and other professionals, and how we might go about achieving it. Consistent with efforts globally (European Commission 2019), our language shifts deliberately from the narrow focus on *open access* and the publication of science and toward the goal of *open science*; a more transparent and open scientific practice that is assumed to ultimately deliver greater benefit for society.

Knowledge creation and dissemination have a complex history within scientific culture (Hessels and van Lente 2008) and have to a large extent been developed around publication methods (Bartling and Friesike 2014). While this explains the focus on open access, open science calls for a cultural change that challenges traditional institutional modes of knowledge creation and dissemination. In some fields, this has been expressed as an increased focus on the commercialisation of scientific research (Caulfield, Harmon, and Joly 2012). For some, this introduces a tension with the open science model that promotes collaboration and open sharing while for others, it signals an opportunity to move more rapidly from research to open innovation and societal impact (Friesike et al. 2015; Tait 2017). However, at the heart of the open science model lies an assumption that scientific research will be guided and developed by its societal relevance (Rosenlund, Notini, and Bravo 2017). Despite this, it is not always clear how that will be achieved or by what measures. We define open science in this research as 'transparent and accessible knowledge that is shared and developed through collaborative networks' (Vicente-Saez and Martinez-Fuentes 2018, 428). This implies moving beyond the traditional modes of knowledge creation and dissemination and a willigness to challenge the way these activities have occurred in universities and research institutions, and that have often been structured around scientific disciplines (Hessels and van Lente 2008). In doing this, we also seek to identify to what extent Australian scientists and researchers identify and challenge their own scientific practice and institutions in advancing the broader goals of open science and if they do, how they anticpate this being realised.

The paper is structured as follows. First, we outline the rationale for conducting this research on open science within the context of responsible innovation in Australia. We then outline the research methods and approaches used to analyse the data collected in this research. Key findings and priorities on transparency and openness in Australian science are presented. We first present the quantitative results that describe expectations and beliefs about current practice, and then analyse the findings of the qualitative data to identify priorities for improving transparency and openness. Finally, we note the limitations of this study, opportunities for further research and conclude with a brief discussion on the implications of this research.

Open science for responsible innovation

The aim of this research is to elicit the perspectives and priorities of scientists, researchers and other professionals working in the Australian research and innovation system on open science in particular, and the implications of this for responsible innovation in Australia, more generally. The concept of responsible innovation has both academic and normative origins inspired by a desire to ensure 'science and innovation are directed at, and undertaken towards, socially desirable and socially acceptable ends, with connotations of trust and integrity' (Owen et al. 2013, 27). While responsibility has always been part of the central narrative of research practice, responsible innovation has emerged over the last decade as a broader framework based on the normative dimensions of building anticipation, reflexivity, inclusion and responsiveness into scientific research practice and the outcomes generated from it (Stilgoe, Owen, and Macnaghten 2013). In many ways, this reframing of responsibility has been a call to lift scientific research practice beyond established codes of conduct and ethical review to realise greater and more tangible societal benefit (Finkel 2019). Importantly, the goal is not to replace those codes and formal requirements, which remain essential to achieving research integrity, but rather to find ways to enhance the value, benefit and impact that can be generated from science for society.

The broad context for this research is framed by the emergent use of the term 'responsible innovation' in Australia, and by the greater need to understand what this really means for both practice and our expectations of research and development in this context (Ashworth et al. 2019). While responsible innovation has been used extensively in Europe over the last decade (Owen, Macnaghten, and Stilgoe 2012; Stilgoe, Owen, and Macnaghten 2013; von Schomberg 2013) and to some extent in the United States (Guston et al. 2014), its adoption in Australia is relatively recent. For example, in 2017, Australia's national science agency and largest PFRA, the Commonwealth Scientific & Industrial Research Organisation (CSIRO) established a new research program in responsible innovation to examine 'the interface of science and technology with society [and] to ensure that emerging science domains can proceed responsibly and deliver positive impacts for society' (CSIRO 2019). In 2018, the Australian Council of Learned Academies (ACOLA) published an outlook report on synthetic biology in Australia that emphasised the importance of adopting responsible innovation in the development of synthetic biology research and industries (Gray et al. 2018). Later that year, the Australian Academy of Science (AAS) called for a framework for responsible research and innovation as a commitment to the idea that the 'Australian community has a right to expect that it will benefit from its investment in science' (AAS 2018, 2). In 2019, the Australian Human Rights Commission called for a responsible innovation organisation to guide and govern the use of artificial intelligence (AI) in Australia (Australian Human Rights Commission & World Economic Forum 2019). This adoption of the concept of responsible innovation by several significant institutions over a relatively short timeframe in Australia highlights growing commitment to generating broader societal benefit from scientific research and innovation. However, there remains a need to examine what this really means in practice.

Open access and open science are terms that are widely used, often interchangeably. They are emerging fields of research and practice in their own right and there are a multitude of definitions and frameworks in use (Vicente-Saez and Martinez-Fuentes 2018). Often however, open science is considered to be comprised of the four components of: *open access*, which refers to making research outputs and publications available; *open data*, which refers to the publication, sharing and re-use of data collected in research; *open source*, which refers to software that can be freely accessed; and *open reproducible research*, which is the practice of open science that will allow for research to be independently reproduced (and includes sharing research practices throughout the course of the work flow, not only the outputs of that research, such as key decisions, data management protocols, software selection, etc.) (Andreoli-Verbasch and Mueller-Langer 2014; Pontika et al. 2015; Sullivan, DeHaven, and Mellor 2019).

However we define these terms, according to the European Commission's H2020 program, open access and open science are a core pillar of responsible innovation (European Commission 2011; Christensen et al. 2020) that will improve the circulation of knowledge in society, foster innovation and strengthen the knowledge economy. This commitment is further extended in the scholarly literature. Rather than open access and open science, Owen et al. (2013) and Stilgoe, Owen, and Macnaghten (2013) work with the dimension of openness in responsible innovation, which they view as open and free access to and communication of the results of research. However, they also extend this to sharing the purposes, risks, uncertainties, implications and potential uses of the research. Sharing this greater range of information about research is thus seen to facilitate more inclusive deliberation in relation to research and its purpose in the world. It is anticipated this will create benefits such as more informed debates, stronger foundations for decision-making, transparency, and more equitable access to knowledge (in turn reducing power asymmetries in a knowledge economy) (Hessels and van Lente, 2008).

Accompanying this, there is also a view that the more familiar people are with science and scientific processes, the more likely they are to trust and support investment in it (Bauer, Allum, and Miller 2007; Stilgoe, Lock, and Wilsdon 2014). Communicating science is one avenue that may contribute to building and maintaining public support (Palmer and Schibeci 2014). Conversely, a lack of engagement between science and society may erode trust in research and public institutions. This assumes an effective relationship between science and society will be built on principles of transparency and openness: '[t]ransparent in the values and assumptions that underpin chosen science pursuits, and open to new ideas, divergent perspectives as well as making scientific research accessible to all levels of a scientifically engaged society' (Herington, Coates, and Lacey 2019, 13).

This range of benefits associated with open science is not unlike the breadth of benefits outlined at the outset of this paper and that are present in the range of open access policies that exist in Australia. For these reasons, we set about examining the views of those working in, managing and funding scientific research in Australia to better understand how they view current practice and future priorities in relation to the role of transparency and openness, and what this might mean for the practice of open science.

Research methods

This research is drawn from a broader study on the science-society relationship and responsible innovation in Australia (see Herington, Coates, and Lacey 2019). The broader study, conducted in April 2019, used an online survey instrument to examine what scientists, researchers and other professionals working in the Australian research and innovation system understand as responsible innovation. The survey was designed to capture both quantitative and qualitative responses of participants. In doing so, we set out to gain an understanding of their expectations of responsible innovation against the following three themes:

- Transparency and openness in research and innovation;
- The role of inclusive, and meaningful dialogue between science and society; and
- Ensuring ethical and responsible conduct of science.

In this paper, we focus only on the findings relating to the theme of transparency and openness in research and innovation.[1] We do this in order to provide a deeper analysis of how scientists, researchers and other professionals understand their own responsibilities in relation to transparency and openness, and what this reveals about how we view open access and open science in the Australian context. Because the concept of open science often carries subjective meanings and is prone to misinterpretation (Fecher and Friesike 2014), we deliberately focused on the principles of transparency and openness in designing this research. The section of the survey on transparency and openness was introduced with the following statement to orient participants:

> A robust, open relationship between science and society requires a foundation built on principles of transparency and openness. This relationship requires transparency about the values and assumptions that underpin research and innovation, and openness to new ideas and divergent perspectives.

The use of definitions and other materials is an accepted approach in survey design that helps to provide a common base for understanding the concepts under consideration and for answering questions about them (Volken, Wong-Parodi, and Trutnevyte 2017; Lacey et al. 2019). Similar definitions were provided for all themes in the survey. Using these guiding principles of transparency and openness, we explore expectations, current practice and key priorities from the perspective of scientists, researchers and other professionals working in the Australian research and innovation system.

Research design and survey

Participants for the survey were recruited via a non-probability, voluntary sampling method through professional networks, institutional internal communication and key informants. This sampling strategy was employed to capture the perspectives of scientists, researchers and other professionals using accessible professional networks, and to facilitate the participation of those interested in doing so. This research did not aim to produce generalisable results with a sole focus on the quantitative data, rather the aims of the research were to capture rich and contextual data from a sample of this group of professionals. The mixed-methods survey questionnaire was deliberatively designed to include complementary quantitative and qualitative items to generate an in-depth dataset. Given the sampling strategy, results from the survey are not generalisable and should not be interpreted as such. Potential participants were provided a link to the survey for online completion. The survey was open for a total of 15 days in April 2019. During this time, 174 responses were recorded, of these, 3 were removed due to invalid responses. Of the 171 valid responses, 123 were complete, having provided answers for all survey items. All valid responses were included in the analyses.

In addition to demographic questions, the survey instrument included a series of Likert scales and open text boxes to capture responses in relation to transparency and openness.[2] The transparency and openness theme included one Likert scale, comprising three survey-items measuring participants' *expectations* of the transparency and openness of scientists, research delivery agencies and research funding agencies; and one Likert scale, comprising nine survey-items that captured what they *believe about the current practice* of science funders, scientists and the institutional arrangements of Australian science funding and research delivery agencies with respect to transparency and openness (i.e. a total of 12 variables were tested). The items included in the Likert scales asked survey participants to indicate their level of agreement with a series of statements on a 7-point scale (1 = strongly disagree, 4 = neither agree/disagree, 7 = strongly agree).

Using the data captured from the survey, we explore the expectations and beliefs of research and innovation stakeholders in Australia to assess the current state of open science. The potential for improving transparency and openness of science practice and expectations are discussed, alongside insights gained from the qualitative data analysis of participants' priorities. Before presenting the results and discussion, we present the analytic approach and participant characteristics.

Analytic approach

The analytic approach used in this paper is suited to the non-probability voluntary sampling strategy employed in generating a participant sample for the survey, and to the categorical nature of the variables of interest from the transparency and openness theme. The survey data analysis presents findings on the perceptions of Australian scientists, researchers and other professionals. It does not attempt to generalise or argue a case for how all Australian scientists and researchers view this sector, nor does it attempt to present reasons for assumptions of causality.

For the purpose of this paper, variables from the transparency and openness theme were analysed with the use of descriptive summary statistics. Tests of association were also conducted to explore whether there may be significant associations between the age, gender and career stage of participants. Relevant literature suggests that participant age would not be significantly associated with perceptions and expectations of open science, but that gender and career stage may (Haeussler et al. 2014). Career stage, as operationalised in the analysis as length of time working in the Australian research and innovation system, may influence participants' perceptions and expectations. Career stage could also be considered as an indicator of participant position or seniority, which may also influence their perspectives of the Australian research and innovation system. We use chi-square statistic to test for associations between the Likert-scale variables capturing transparency and openness perspectives and the demographic characteristics of participants. The distribution of responses on both demographic and Likert-scale variables presented challenges as participant responses were often skewed. Coupled with the small sample size, these distribution characteristics meant that many of the contingency tables of the open-science and demographic variables did not meet the Pearson's chi-square assumptions and therefore had potential for a Type II error. The tests of association are reported later in the paper with these caveats taken into account. For the quantitative data analysis, we used the general-purpose statistical software package Stata (StataCorp 2017).

In order to contextualise the quantitative findings, we also present a qualitative analysis of participants' priorities on transparency and openness. The survey instrument included an open-ended text question seeking participants' top three priorities or issues related to transparency and openness in the Australian research and innovation sector. Each participant was asked to write only one or two sentences per priority and further ranking of their top three priorities was not required. Collectively, participants submitted 303 priority or issue statements on transparency and openness. An Automated Content Analysis (ACA) was conducted on this data using the computer-aided software package Leximancer (Smith and Humphreys 2006).

ACA is a text-mining method that uses text-parsing and machine learning to discover and learn, based on data and a suite of algorithms, key concepts, topics and themes (Blei 2012). ACA generally follows a three-stage approach (Nunez-Mir et al. 2016). First, concept seeds are identified using either unsupervised concept seeding (automated) or supervised via selection. Second, concepts are developed and defined using text-grounded, word disambiguation and/or user-defined thesaurus construction. Third, original text is re-classified based on the learned concepts and indexed accordingly. The final outputs from an ACA procedure may include concept maps, trend analyses and reports detailing concept occurrence and co-occurrences.

Following ACA procedures, Leximancer can reliably and reproducibly identify main concepts and themes embedded within text, based on the frequency and patterns of co-occurrence. Leximancer was employed to interrogate the priority statements for emerging subthemes in the text. In this way, Leximancer serves to reduce the risk of subjectivity and bias (Sotiriadou, Brouwers, and Le 2014) during the initial stages of an inductive, exploratory qualitative data interrogation such as this research. Specifically, we used Leximancer to analyse all priority statements from respondents submitted through the survey, to automate the process of determining key themes and concepts found in these statements. The data was then further qualitatively codified, that is each priority statement was coded into one of the four emergent thematic areas, to interpret and articulate these identified themes. Before presenting the quantitative and qualitative results, we outline the participant characteristics.

Participant characteristics

Table 1 presents the demographic characteristics of the survey participants. Nearly half of participants were male (46.2 per cent), 52.6 per cent were female and 1.2 per cent responded as other. Most participants were aged between 40–49 years (31.5 per cent) or 30–39 years (26.4 per cent). As might be expected, nearly all participants held a postgraduate qualification (89.5 per cent). Academic career stage was measured by calculating the number of years since completion of postgraduate qualification, as a substitute measure of PhD conferral. Just under half of the participants (47.4 per cent) were established in their career having completed postgraduate studies prior to 2003. Most participant workplaces were in either

Table 1. Survey participant characteristics (*n*, column per cent).

	No.	%		No.	%
Gender			**State/Territory of workplace**		
Male	79	46.2	New South Wales	53	31.2
Female	90	52.6	Queensland	50	29.4
Other	2	1.2	Victoria	34	20
Total	171	100	Western Australia	22	12.9
Age			South Australia	4	2.4
20–24 years	2	1.2	Tasmania	2	1.2
25–29 years	10	5.8	Northern Territory	2	1.2
30–34 years	23	13.5	Australian Capital Territory	1	0.6
35–39 years	22	12.9	Overseas	2	1.2
40–44 years	24	14	Total	170	100
45–49 years	30	17.5	**Remoteness area**		
50–54 years	19	11.1	Major City	155	92.3
55–59 years	16	9.4	Inner Regional	7	4.2
60–64 years	15	8.8	Outer Regional	6	3.6
65–69 years	4	2.3	Total	168	100
70–74 years	4	2.3	**Employer Industry (ANZSIC)**		
75–79 years	1	0.6	Tertiary Education	121	73.8
80–84 years	1	0.6	Scientific Research Services	28	17.1
Total	171	100	Civic, Professional & Other Interest Group Services	4	2.4
Indigenous status			Management and Related Consulting Services	2	1.2
Indigenous	1	0.6	Central Government Administration	2	1.2
Non-Indigenous	166	99.4	Land Development and Site Preparation Services	1	0.6
Total	167	100	Computer System Design and Related Services	1	0.6
Highest level of education			State Government Administration	1	0.6
Postgraduate level degree	154	89.5	Justice	1	0.6
Graduate diploma and graduate certificate	6	3.5	School Education	1	0.6
Bachelor degree level	11	6.4	Hospitals	1	0.6
Certificate level	1	0.6	Museum Operation	1	0.6
Total	172	100	Total	164	100
Career stage			**Occupational category**		
Early	37	24	Researcher/scientist	72	42.6
Mid	44	28.6	Teaching and research academic	44	26
Established	73	47.4	PhD student	16	9.5
Total	154	100	Science/research manager	14	8.3
Year completed highest level of education			Policy manager	8	4.7
2019–2014	45	26.2	Consultant	4	2.4
2013–2004	50	29.1	Educator	3	1.8
2003 and earlier	77	44.8	Other	8	4.7
Total	172	100	Total	169	100

New South Wales or Queensland at 31.2 per cent and 29.4 per cent, respectively, and nearly all were located in a major Australian city (92.3 per cent).

Our sampling and recruitment strategy targeted publicly funded research agencies (i.e. PFRAs) and higher-education institutions (i.e. universities), which comprise two of the major research implementation functions in Australia (Lacey, Ashworth, and Witt 2019). This is illustrated in the participants' place of work and occupation type. Participants were asked the name of their employer. These responses were coded according to the Australian and New Zealand Standard Industrial Classification (Australian Bureau of Statistics 2016). Most survey participants worked for an employer in the tertiary education industry (73.8 per cent), or at a scientific research institution (17.1 per cent). Occupational categories were thematically coded, using the open-text responses provided by participants on questions about their primary occupation and primary responsibility in their role. The occupational categories aimed to capture both the main occupation of the participants and their position in the Australian research and innovation sector. For example, participants coded to the 'science/research manager' category had a role in overseeing or managing science or research work and typically included occupation titles such as, 'Faculty Dean' or 'Senior Research Manager'. Most survey participants were employed as either researchers/scientists (42.6 per cent) or as teaching and research academics (26 per cent).

Differences in some of the demographics, such as career stage, employer industry or occupation of survey participants may potentially influence participants' relationship to stakeholders in the Australian research environment and therefore may also affect their perspectives on the nature of the science-society relationship. In capturing this data, we aimed to quantify the variety of roles and positions of the participants in the research and innovation sector in Australia, and to allow for further analysis of any potential variations in the perspectives and opinions expressed by participants. In the next section of the paper, we present summary statistics of the opinions and perspectives of participants on questions about transparency and openness, followed by results on associations between participant career stage, occupation and employer industry.

Results and discussion

In this section, we first present the findings from the descriptive analysis of the quantitative survey items of interest. The descriptive statistics suggest a discrepancy between what the survey participants expect from scientists, research delivery agencies and research funding agencies in terms of transparency and openness, and what they perceive to be happening in the current practice of these stakeholders. We then present the findings from the ACA of the open-text responses from participants on transparency and openness. These extend the descriptive statistics findings with several themes about what participants identify as their priorities for strengthening open science in Australia. These suggestions may help mediate the discrepancy between expectations and current practice.

Open science expectations and perceptions of current practice

Participants were asked to rate their level of agreement with a series of statements about their expectations of scientists, research delivery agencies and research funding agencies following principles of transparency and openness in their practice. Figure 1 illustrates

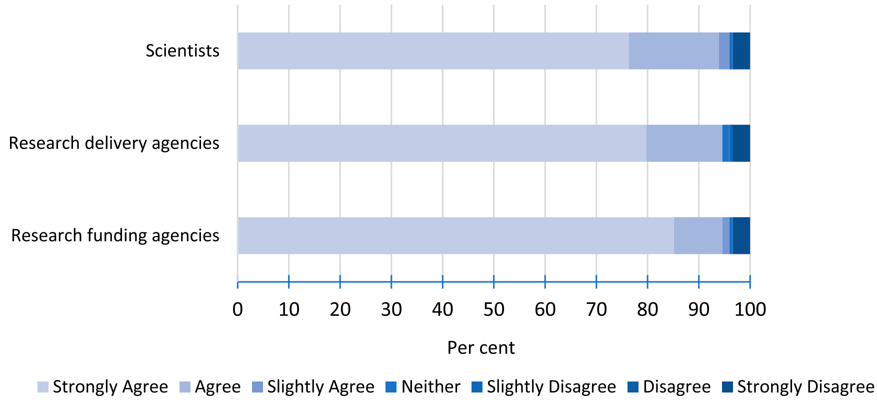

Figure 1. Expectations of Australian stakeholders to follow principles of transparency and openness (per cent).

Note: Participants were asked: 'Please rate the extent to which you agree or disagree with the following statements'. The statements were the same for each stakeholder, as follows: 'I expect [Australian stakeholders] to follow principles of transparency and openness'.

that the survey participants hold high expectations of key stakeholders in the Australian research and innovation system to follow such principles. The majority of participants strongly agreed that scientists (76.35 per cent), science delivery agencies (79.73 per cent) and science funding agencies (85.14 per cent) should follow principles of transparency and openness. When responses for agree and strongly agree categories are combined, we can see that the majority of participants, at about 94 per cent for each statement, are in high support for principles of transparency and openness.

Participants were also asked about their level of agreement with statements about the current practice of science funding stakeholders in Australia. As presented in Figure 2, the statements explored the communication of decisions from various avenues for science funding in Australia, namely government, philanthropic and private/industry funders. Overall, the data from these three items indicated that survey participants have low levels of confidence that Australian science funders are effectively communicating their decisions to the public. Over 50 per cent of participants slightly to strongly

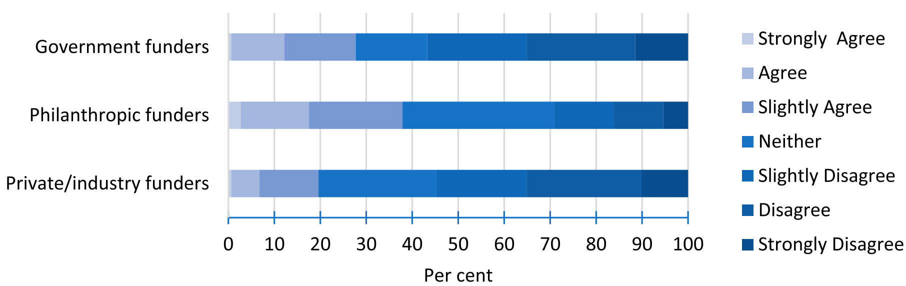

Figure 2. Beliefs about Australian science funders effective communication of decisions to the Australian public (per cent).

Note: Participants were asked: 'Please rate the extent to which you agree or disagree with the following statements'. The statements were the same for each stakeholder, as follows: 'I believe [government funders, philanthropic funders, private/industry funders] of Australian science effectively communicate their decisions to the Australian public'.

disagreed that government and private/industry funders (56.76 and 54.73 per cent, respectively) effectively communicated their decisions to the Australian public. The responses to these items also suggest an uncertainty about the communication of decisions by philanthropic funders, with over a quarter (33 per cent) of participants stating they neither agreed nor disagreed. A quarter of participants were also ambivalent about private and industry funders' communication. However, more participants agreed (37.8 per cent) that philanthropic funders communicated their decisions, than disagreed (29 per cent) when responses from slightly-strongly agreed, and slightly-strongly disagreed, were combined. This was not the case for government and private/industry funders, with more participants disagreeing than agreeing with these statements. Overall, the responses to the statements on key stakeholders' communication of their decisions suggested participants have generally negative, or ambivalent beliefs, which may be illustrative of an underlying perception of a lack of transparency and openness from these funding bodies.

Figure 3 presents participant perspectives of the communication and conduct of Australian scientists with respect to transparency and openness. Whilst most participants believe the conduct of Australian scientists is transparent and that they effectively communicate with the public, many also thought that Australian scientists could do better. When slightly-strongly agree responses are combined, 53.39 per cent of participants agree that Australian scientists effectively communicate their research to the Australian public, and 64.87 per cent agree that Australian scientists' conduct is transparent. However, the majority of responses in the agree categories are in the slightly agree or agree range, suggesting that participants were not overall in strong agreement with these statements. Further, in comparison to the responses to research funding stakeholders, the survey data shows that participants perceive scientists to be better placed to communicate to the public than research funding bodies.

Questions were also included in the survey to gauge perceptions on how current institutional arrangements encourage transparency and openness from Australian scientists, as shown in Figure 4. Institutional arrangements are broadly taken to encompass the collection of policies, systems and processes within research delivery and research funding organisations that enable them to plan, manage and deliver their activities effectively. These questions provide further context to the responses to previous questions in that

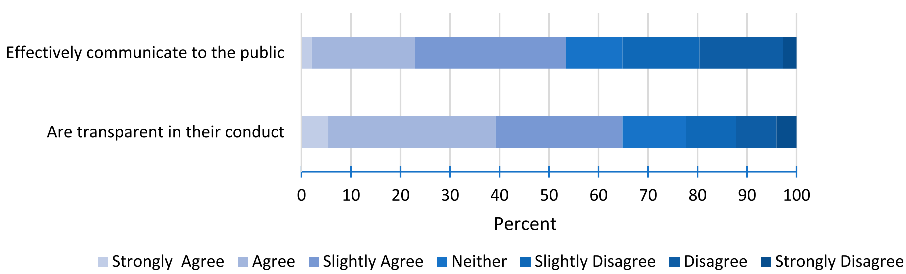

Figure 3. Beliefs about communication and conduct of Australian Scientists.

Note: Participants were asked: 'Please rate the extent to which you agree or disagree with the following statements'. The statements were: 'I believe Australian scientists effectively communicate their research to the Australian public', and 'I believe the conduct of Australian scientists is largely transparent'.

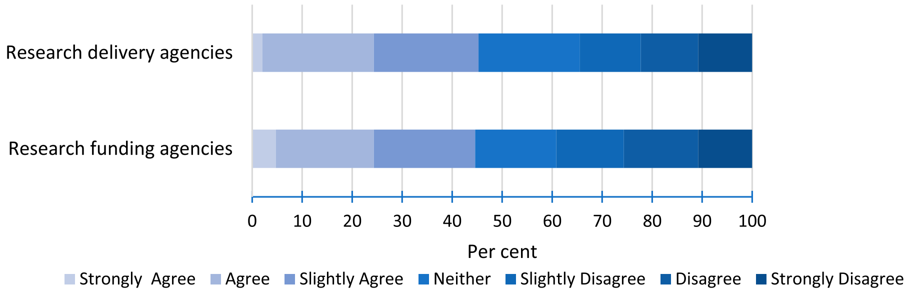

Figure 4. Research funding/delivery agency institutional arrangements encourage transparency and openness.

Note: Participants were asked: 'Please rate the extent to which you agree or disagree with the following statements'. The statements were the same for each stakeholder, as follows: 'I believe the current institutional arrangements in [research delivery agencies/research funding agencies] encourage openness and transparency from our scientists'.

it not only highlights a potential gap between expectations and current practice for open science in the Australian research and innovation system, but it also begins to highlight why such a gap may exist. Less than half of participants agreed that institutional arrangements encourage transparency and openness (45.28 per cent for research delivery agencies and 44.59 per cent for research funding agencies), with a substantial proportion of responses in the 'neither' category at 20.27 and 16.22 per cent, respectively. These responses, while mostly suggesting that research agencies support transparency and openness, indicate that greater transparency and openness is perceived to be constrained by institutional arrangements within research funding and delivery agencies. In other words, many participants believed that better facilitation and support through institutional arrangements in science delivery and funding for these core principles of scientific best practice are required.

Finally, overall perceptions of transparency and openness were measured with respect to science funding and the accessibility of science to the public (Figure 5). Responses to these general statements about transparency and openness suggest that, overall, participants believed science funding decisions are not particularly transparent, nor is science

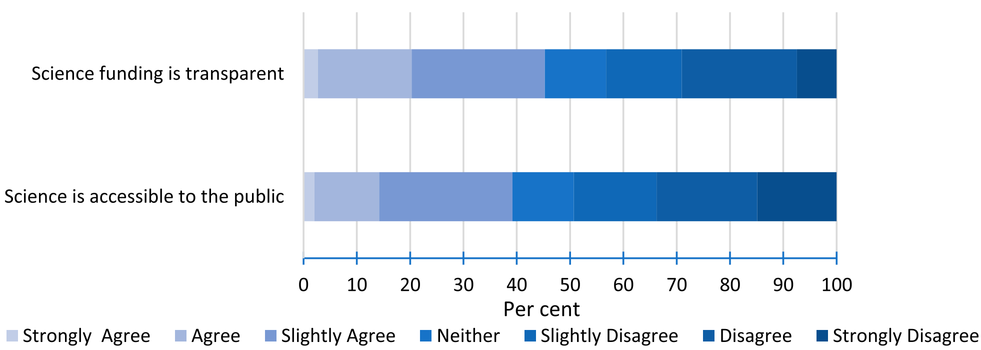

Figure 5. Overall perceptions of transparency and openness in Australian science.

Note: Participants were asked: 'Please rate the extent to which you agree or disagree with the following statements'. The statements were: 'On the whole, I feel scientific research is accessible to all levels of a scientifically engaged public', and 'I believe the current decisions about the funding of science are largely transparent'.

generally accessible to the public. Most survey participants perceived scientific research to not be accessible to all levels of a scientifically engaged public, though slightly more participants believed that current decisions regarding the funding of science are transparent. For instance, when the slightly-strongly disagree, and slightly-strongly agree statements are combined, slightly more participants agree that science funding decisions are transparent (45.27 per cent) than disagree (43.24 per cent). While for the statement on science being accessible, more participants disagreed (49.32 per cent) than agreed (39.19 per cent). For both statements, one-quarter of participants selected the 'neither agree/disagree' response. This suggests either complacency on these statements, or a lack in confidence to respond either favourably or unfavourably with respect to general perceptions of the transparency of funding and accessibility of science to the Australian public.

Are demographic factors associated with perceptions of open science?

Demographic characteristics of participants were also tested for significant association with the transparency and openness survey variables. Age, gender, occupation and career stage were included in this analysis. However, the distribution of the sample meant that many of the contingency tables did not meet the assumptions of the Pearsons chi-square test and therefore produced invalid results. To increase the suitability of the data for the contingency tables, response categories for occupational category were combined to produce more robust results. Strongly, slightly and disagree categories, and strongly, slightly and agree categories were also combined due to response distribution sparseness.

Age and gender did not produce any statistically significant associations with any of the transparency and openness variables. The lack of statistical significance of age of respondents is consistent with a study by Haeussler et al. (2014) on sharing in science practice, though not for gender. Haeussler et al. (2014) found males to be less likely to share in their science practice than females. The results on age and gender should be interpreted with caution, however, due to the aforementioned chi-square test assumption violation.

Some statistically significant and valid associations were found with career stage and occupation. Occupational category of participants was tested for association with each of the 12 variables measuring perceptions and opinions of transparency and openness. Of these 12 variables, we found significant association with participants' level of agreement that government funders effectively communicate decisions ($p < 0.05$). Overall, most participants disagreed with the statement that government funders effectively communicate funding decisions, with 53.9 per cent of researchers and scientists disagreeing with the statement, 55 per cent of academics, 63.2 per cent of managers, and 90 per cent of 'other' occupations, which included consultant, educators and independent professionals, disagreeing. A statistically significant association between participant level of agreement that science funding overall is transparent ($p < 0.05$) and occupation was also found. More academics and managers (both 47 per cent) disagreed with this statement than researchers/scientists (37 per cent).

Career stage was also tested for association with each of the 12 variables measuring perceptions and opinions of transparency and openness. Of the 12 variables, we found significant association with participants level of agreement that government and philanthropic funders communicate decisions effectively (both $p < 0.05$). Slightly more early to mid-career participants (60 per cent for both) disagreed that government funders effectively communicate decisions, than established career participants (53 per cent). While beliefs on philanthropic funding decisions communication was associated with career stage, responses between career stage were fairly uniform across disagree, neither and agree response categories.

Career stage was also statistically significantly associated with levels of agreement on the belief that institutional arrangements of research delivery agencies ($p < 0.05$) and research funding agencies ($p < 0.01$) encourage transparency and openness. Early career participants disagreed more than mid or established career participants that the institutional arrangements of research delivery and funding agencies (40 per cent and 51.4 per cent, respectively) were transparent. The responses of early career participants also suggest greater ambiguity about institutional arrangements for research delivery and funding agencies though; for both items early career researchers were proportionality more unsure.

Priorities for strengthening open science in Australia

Survey participants were also asked to qualitatively describe their top three priorities or issues to ensure transparency and openness in an open-text response question. A total of 303 priority statements were submitted and clustered around issues related to: science outreach ($n = 111$), science funding ($n = 100$), openness and open access ($n = 68$) and media engagement ($n = 24$). We examine each theme in turn.

Science outreach and the transition from deficit to dialogue

The theme of science outreach broadly relates to how science is used to engage and communicate with various stakeholders, including society generally. It includes commentary and priorities on: (1) with whom science is, or ought to be, engaging, (2) what information to provide and/or collect, and (3) how to go about this engagement. It is the most dominant theme to emerge from the data with 111 priority or issue statements coded against it.

In analysing the priority statements for this theme, participants generally perceived that open science is not simply a matter of improving the one-way communication between science and society but requires opening a two-way dialogical form of public engagement. Such a shift from 'deficit to dialogue' (Stilgoe, Lock, and Wilsdon 2014, 5) is consistent with the transition found in the literature on public understanding of science and reflects a move away from what has been described as the traditional deficit model. In the deficit model, the issue of poor public engagement is framed as a lack of knowledge among the public and the solution is, therefore, always framed as a need to provide more information (Hansen et al. 2003; Sturgis and Allum 2004). In the words of participants, the priority for this transition was described as follows:

> There are too few avenues for 'society' to engage in development of research agendas – 'society' is typically only thought of as the consumers at the end of a long scientific process.

> Transforming concepts of 'transparency and openness' from their current focus on the communication of research outcomes to a more transparent discussion of, and dialogue around, the values underpinning research.

But do scientists have the means and the capability to move from deficit to dialogical science outreach? And what should they be doing to create or support these dialogues with diverse publics? The data alluded not only to transitions in the nature and scope of science outreach activities, but also the skills and competencies required to enable this transition. A further challenge arises in thinking about the scale of such efforts. As Stilgoe, Lock, and Wilsdon (2014) point out the scale of public engagement when it does happen often resembles the 'mini-publics' described by Goodin and Dryzek (2006); small enough to be deliberative and representative in democratic terms but not statistically representative of the wider public. While these small and targeted engagements make an important contribution and may be important for specific or even political ends, they in no way reflect the global scale of the scientific endeavour and the potential of open science as it is often framed. While most participants believed that science was not accessible to all levels of scientifically engaged public and recognised the role of science outreach, a deeper analysis of why public engagement, and to what end, is needed to navigate a more considered approach to the institutional arrangements that might enable this approach.

Transparency of science funding

A total 101 priority statements clustered within this theme relate to the transparent and open nature of science funding. Although most statements referred to publicly funded research mechanisms, several priorities highlighted the need for increased transparency of industry-funded research (and to a lesser extent, philanthropic funding). In the discussion of transparency of funding, one participant expressed this as follows:

> Public transparency and public accountability for research funded by all sources, but particularly government (taxpayer accountability) and industry (to ensure scientists are not pressured by industry objectives to moderate findings).

While there were some concerns noted about potential political or industry interference in funding decisions (or the research generated as a result), there was a much greater focus on the need to ensure public or taxpayer accountability for funding decisions. The mechanisms suggested for achieving this ranged from including the public in funding decisions (e.g. via public representation on review committees), applying tests for taxpayer accountability using criteria such as equity and inclusivity, clearly demonstrating that societal input was incorporated in funding decisions, through to simply making the funding decisions publicly available. While major research funders in Australia already apply criteria that requires evidence of how the research is in the national interest (ARC 2015), the data indicated that these suggestions for increasing accountability of funding was seen as a pathway for building public confidence in science. However, the drivers of trust in science are complex; how and to what extent transparency of funding decisions contributes to public trust needs to be tested (Peerenboom 2002; Funk 2017).

This desire for increased transparency of funding was not only directed at the public. Many of the priority statements also highlighted an overarching desire for greater clarity about funding processes and decisions from the participants themselves. These findings are consistent with the descriptive statistical analysis on overall perceptions of transparency and openness in Australian science, where 55 per cent of participants either disagreed or were ambiguous (responding 'neither') to a statement on the transparency of science funding. There was some evidence in the ACA results that career stage may play a role in how transparency of funding was perceived with some priority statements calling for track record to be removed as a criterion for research awards, that increasing transparency would end the perceived practice of 'captain's picks', and a general desire to see more evidence of the outcomes of national funding decisions. The role of competition also emerged in this theme expressed by one participant as follows:

> Scientists are forced to be competitive with each other rather than collaborative, especially within a diminishing market.

Here the call was for better institutional arrangements and support from research funding agencies to better facilitate collaboration, including multidisciplinary collaboration. This finding was also consistent to the tests for statistically significant associations between levels of agreement on the belief that institutional arrangements of research delivery agencies ($p < 0.05$) and research funding agencies ($p < 0.01$) encourage transparency and openness. As reported earlier in the paper, early career participants disagreed more with these statements than mid or established career participants. Haeussler et al. (2014) have examined patterns of information sharing among academics and have found that this tends to be context dependent depending on the trade-offs between the potential for greater reciprocity and a loss in competitiveness. In their research, career stage played a role in reducing information sharing behaviours in individuals but only where the researcher held an untenured position. This matters as if we are truly contemplating the broader societal value generated by open science, because it means this outward impact from scientific research needs to be aligned with professional recognition and incentives for individuals. While research institutions in Australia are increasingly moving toward impact reporting, professional recognition and career advancement for scientists and researchers continue to be aligned with publications, awards, and the ability to secure increasingly competitive funding grants (Panaretos and Malesios 2009; Lacey et al. 2015; Finkel 2019). This also points to the need to better understand both research and innovation system level mechanisms for enabling transparency that will occur at and across organisational scales and how individuals will operate within and assess the benefits of these systems at the personal scale.

Openness and open access

There were 68 priority statements that highlighted the terms 'openness' and 'open access'. The analysis of this data suggests an emerging distinction between the concept of openness (to differing perspectives, values and priorities) and the concept of open access to scientific outputs as might be traditionally understood. It also suggests there are still varied understandings and expectations of these terms in the practice or experience of scientists and researchers (Vicente-Saez and Martinez-Fuentes 2018) and they continue to be conflated or used interchangeably. In distilling the differences between how the terms were used by participants, our analysis revealed that the terms most frequently associated with the narrower framing of open access tended to refer to publications, data, cost and resourcing issues. In many ways, this reflects the focus on improving cost efficiencies in the publication process (Productivity Commission 2016), which was summarised at the outset of this article. Participants were clear in their views that scientific publications, particularly those that had been publicly funded, should be made freely accessible. Furthermore, some priority statements addressed possible constraints to achieving the goal of open access, including resourcing requirements and information sensitivities. For example:

> There needs to be a system to fund open-access publications. The high cost of open access outlets ensures a good deal of research cannot be published in a manner that is freely accessible to the public, particularly research from junior scientists.

The above quote also highlights this as a specific challenge for early career scientists and researchers, emphasising that traditional forms of professional recognition, such as research outputs, remain critical to career advancement and reward. However, this was accompanied by some caution about the need to also acknowledge when open access to all data and information may not always be the most appropriate or best outcome:

> Determine what should or shouldn't be transparent or open. Some archives contain records that were not intended for publication, e.g. sensitive, personal, commercial information. Archives must have appropriate licencing and access protocols and obligations that enable transparency and openness as appropriate.

What distinguished the priority statements that were more aligned with openness was a shift away from accessibility to research outputs and toward higher order goals such as incentives, transparency and accountability. Here the tendency was to move toward the more expansive potential of open science, or openness as described in the responsible innovation literature (Owen et al. 2013; Stilgoe, Owen, and Macnaghten 2013). What did emerge in this data was a desire to see increased transdisciplinary research valued and recognised and the inclusion of cultural knowledge, experiential knowledge and local knowledge valued and recognised alongside scientific knowledge. Finally, openness was also understood as a way of achieving greater inclusion and diversity in science and research, and there was emphasis on removing barriers based on gender and ethnicity in research and public institutions. In this interpretation, participants identified an avenue for openness to make scientific research itself more open to diverse participation as a way of generating the knowledge that would respond to multiple needs and perspectives in the world.

Media engagement

This final theme encompasses priorities concerning transparent and responsible engagement with the media. Given that greater calls for openness and transparency have highlighted a role for increased public engagement and science communication on the part of scientists and researchers, it is acknowledged that the media has a role to play in influencing how the public might interact with science (Holliman et al. 2009). While this emerged as the least dominant theme (24 statements), it is of interest as it looks at the role of those beyond the research and innovation system in enabling transparency and openness. The priorities vary from normative issues related to the nature of media engagement and responsibilities to more tangible and direct suggestions. For example, there was a clear focus on ensuring responsible reporting of science in the media, including from research institutions, and concerns that media reporting tended toward sensational claims:

> Accuracy in institutional (academic) media and press releases about their scientific research, avoiding hyperbole that leads to misalignment of public expectations versus scientific reality.

There is extensive literature on the use of media to increase knowledge about science, create more interest in science, inform beliefs about science, and contribute to higher trust in scientists (Nisbet et al. 2002; Hwang and Southwell 2009; Retzbach and Maier 2014). However, the data revealed a focus on the training and skills required; both for scientists in engaging with media but also for media, in terms of better understanding and communicating scientific studies. In this case, there seemed to be a desire to improve the nature of the relationship between science and the media, both to address perceptions that media engagement had been detrimental in the past but also where such engagement could improve the societal reach and impact of science.

Limitations and further research

As noted earlier, this research is based on a non-probability, convenience sample and therefore it is important to refer to these limitations in interpreting the findings. However, though a non-probability sampling technique was used, the demographic characteristics of the participants are still typical of those working in the Australian research and innovation system, and hence provide valuable data for understanding current perspectives on open science for responsible innovation in Australia. The nature of this research meant that gaining the unique perspectives of this sub-set of the Australian population was essential. The study was not designed to draw statistically generalisable conclusions about the broader Australian population. Rather, intended as exploratory by nature, this research provides important preliminary data on the perceptions and opinions of the Australian science and research professionals surveyed. We specifically employed a research design that targeted science and research professionals to access their unique perspectives on the Australian research and innovation system. By utilising this approach, this paper empirically contributes to responsible innovation literature and theory, and to a greater understanding of open science in the Australian research and innovation system. To that end, while the four priorities that emerged are instructive, they also require further examination and qualification. This could lead to a more effective exploration and development of models for more inclusive and deliberative governance of science in Australia, a closer examination of the perceived unmet expectations of scientists and researchers about transparency and openness, and to test the views expressed in this research against the expectations of the public in terms of the value of open science.

Conclusion

This research presented the perspectives of 171 scientists, researchers and other professionals working in the Australian research and innovation system on the role of open science for responsible innovation. Openness, open access and open science are appearing more frequently in Australia and around the world, but often used interchangeably to describe multiple benefits, both perceived and anticipated. It was our aim with this research to deliberately move beyond the narrow concept of open access and toward the more expansive goal of open science to see how such a practice might deliver greater benefit for society. We also sought to examine the extent to which Australian scientists and researchers identified and challenged their own scientific practice and institutions in advancing the broader goals of open science.

One clear finding to emerge was a gap between expectations and beliefs about current practice on the transparency and openness of scientists, research delivery agencies and research funding agencies. There was strong agreement among participants with commitment to these principles but comparatively low levels of confidence that funders were transparently communicating their decisions. These views on funding also emerged as one of the key priority areas identified by participants, revealing a belief that transparency of funding was linked to public accountability and higher levels of public trust in science, accompanied by a shared view that science is not accessible enough to the public.

While these results revealed perceptions of current practice in Australia, the participants identified their priorities for improving transparency and openness into the future. The strongest attention was levelled at the role of science outreach and transparency of funding. In relation to science outreach, there was a recognition that public engagement was important but a lack of clarity expressed as to why or how it might occur. In relation to science funding, the challenge of operationalising transparency and openness at the organisational versus individual scale was raised, highlighting the challenges associated with competition in research and the problem of individual career incentives not being aligned with generating greater public value and impact from science. Naturally, these issues have implications for the nature of resourcing, reward mechanisms, competition and organisational culture across the research sector but it also identifies a strong focus on creating greater transparency of traditional modes of knowledge creation and dissemination among those already engaged in the system. This is a useful finding as it suggests that transparency and openness are also important to building awareness of existing institutional arrangements and knowledge production modes; not necessarily to disrupting or challenging them. While there was some evidence of engaging with different forms of knowledge beginning with multidisciplinary modes and moving outward into society, there was a higher level of attention focused on open access to data and publications (again prioritising traditional modes of knowledge creation and dissemination albeit with greater transparency and wider access).

At the outset of this paper, we proposed that responsibility for enabling openness and transparency was not only the responsibility of scientists and researchers but would be necessarily shared with the broader research and innovation system, including the institutions that fund and support the delivery and dissemination of scientific research and innovation, and the media. While the engagement with media highlighted a more traditional science communication role, there is opportunity to think beyond the media as a mere conduit to the societal impact of scientific research. Specifically, our research highlights the importance of understanding the specific range of responsibilities of open science across different institutions (i.e. research implementing organisations such as universities, PFRAs and research funders and managers) (Christensen et al. 2020). The interchanging use of terminology and the focus on greater transparency within existing knowledge creation and dissemination systems suggested that the open science debate in Australia is still emergent. There is a level of familiarity and comfort with open access but a less shared view of more collaborative or deliberative modes of open science and the nature of the value that would be delivered by adopting such approaches.

While these insights have provided preliminary data on the current views and priorities on open science for responsible innovation in Australia, one aspect that was notably absent was a focus on alignment with societal relevance among the suggested priorities expressed in the study (Rosenlund, Notini, and Bravo 2017). Here there is a need to understand the expectations of the public. Are their expectations for increased transparency and openness the same as those working in the research and innovation system? What are their expectations of how science can contribute to a better world? The real end game appears to be in understanding these questions about open science from a broader societal perspective. Only then can we begin to articulate what open science means in an Australian research and innovation context, and the kinds of activities that may help policymakers and research institutions move beyond open access and operationalise open science for responsible innovation as more than a mere aspiration.

Notes

1. As described here, open science is not the sole focus of the broader research and survey, but rather one theme among others including ethical scientific practice and the nature of the dialogue between science and society. The results of the full survey have been reported elsewhere (see Herington, Coates, and Lacey 2019).
2. The full survey instrument has been published in Herington, Coates, and Lacey (2019).

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Article

Open Science and Its Enemies: Challenges for a Sustainable Science–Society Social Contract

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Abstract: Science as a social institution has evolved as the most powerful, highly influential, and sought out institution after the conflicts between science and religion following Galileo. Knowledge as a public good, scientific peer review of science, the prominence of open publications, and the emphasis on professional recognition and scientific autonomy have been the hallmark of science in the past three centuries. According to this scientific spirit, the scientific social system and society formed a unique social contract. This social contract drew considerable institutional and state legitimacy for the openness and public good of science in the service of state and society, all through the post-war period. Openness and public good of science are recognized and legitimized by the scientific community and science agencies at the global level. This paradigm of open science, in varying forms and manifestations, contributed to the progress of systematic knowledge at the service of humankind over the last three centuries. Entering the third decade of the 21st century, the social contract between science and society is undergoing major changes. In fact, the whole paradigm of open science and its social contract is being challenged by various "enemies" or adversaries such as (a) market-based privatized commercial science, (b) industry 4.0 advanced technologies, and (c) a "new iron curtain" on the free flow of science data and information. What is at stake? Are there major changes? Is the very social institution of science transforming? What impact will this have on our contemporary and future sustainable society? These are some important issues that will be addressed in this article.

Keywords: ethos of science; science and society social contract; open science; industry 4.0; platform capitalism in science

1. Introduction

The conflict between science and society after Galileo in the 17th century finally led to the social legitimacy of science. Science, scientists, and society have waged an unrelenting struggle against religion and other social forces in different periods. In doing so, they allocated a relatively independent space for science to promote a systematic understanding of nature and natural phenomena, thereby benefiting the entire society. These struggles paved the way for solid foundations of scientific method and at the same time generated voluntary support and legitimation from the society towards systematic knowledge. The historical period of renaissance and the scientific revolution, perhaps the most significant period of discovery, demonstrated methods of science for the growth of scientific knowledge in the modern era (see ref. [1,2]). In no uncertain terms, this was indeed an open science, accessible not only to fellow scientists and peers but in various forms for the benefit of society at large. Open science should not be confused with the publication of available scientific information and knowledge on non-refereed online sources, which have proliferated in the last decade. The connotation of open science is similar to good science, and the recent report of The Royal Society, London (2012) clearly explains the merits of open science in its *Science as an Open Enterprise* [3]. As the Royal Society [3] (p. 8) observes, "not only is open science often effective in stimulating scientific discovery, it may also help to deter, detect and stamp out bad science. Openness facilitates a systemic integrity that is conducive to early identification of error, malpractice and fraud, and therefore deters them. But this kind of transparency only works when openness meets standards of intelligibility and assessability—where there is intelligent openness."

Since the 17th century, the scientific social system has developed into one of the most powerful, influential, and popular institutions. Knowledge as a public good, scientific peer review, the prominence of publications, and the emphasis on professional recognition and scientific autonomy according to scientific priorities, remained the hallmarks of science in the past three centuries. American sociologist, Robert Merton's classic thesis on *Science, Technology and Society in Seventeenth Century England* [4], led to what has come to be known as the most important "paradigm" of autonomous and open academic science encapsulated in his "ethos of science" or "normative structure of science" [5]. Science as a social institution is based on the ethos of *universalism, communalism, disinterestedness, and organized skepticism*, which remains the cornerstone of open science and is tacitly practiced by the world scientific community in its varying forms. Universalism embodies the objective characteristics of science because acceptance or rejection does not depend on social or personal attributes. The spirit of communalism is opposed to secrets and property rights. Selflessness makes people notice the enthusiasm for knowledge, the lazy curiosity, the altruistic concern that is beneficial to mankind and society as a whole. Organized skepticism means the concept of doubt or scientific temper because it is seen as a methodology and an institutional task. Researchers need to suspend their judgments until the facts are before their eyes. They need to evaluate their beliefs in science based on new empirical evidence. These scientific norms are still the foundation of the relationship between science and society [5]. As Merton defines and explains:

> The ethos of science is that affectively toned complex of values and norms which is held to be binding on the man of science. The norms are expressed in the form of prescriptions, proscriptions, preferences and permissions. They are legitimized in terms of institutional values. These imperatives, transmitted by precept and example and reinforced by sanctions are in varying degrees internalized by the scientist, thus fashioning his scientific conscience or, if one prefers a latter-day phrase, his superego. Although the ethos of science has not been codified, it can be inferred from the moral consensus of scientists ... in countless writings toward contraventions of the ethos [5] (pp. 66–67).

This social contract drew considerable intellectual, institutional, and state legitimacy for the openness and public good of science in the service of state and society all through the 20th century. The *Humboldt Model* of organizing universities, after the establishment of Berlin University, gained prominence in Germany and other European countries. When Britain established the Department of Scientific and Industrial Research (DSIR) around 1918, it assigned tremendous autonomy to the council in peacetime. One is referring to the Haldane Principle. Haldane served as the chairman of the committee that recommended this policy between 1909 and 1918 (see ref. [6]). Similar was the case of other scientific research councils in Canada, Australia, India, and South Africa during the 1950s. Academic or basic research gained tremendous policy support in this period. In the USA, the *Science: The Endless Frontier* (1945) report [7], provided an important linear model of innovation for the growth of an autonomous science and society relationship. The era of the linear model of innovation gave a big boost to basic and fundamental research. The very establishment of the National Science Foundation and its fourfold increase in research funding during the 1950s and 1960s is not unrelated to the *Science: The Endless Frontier* report [7]. Michael Polanyi advocated the freedom and autonomy of scientific institutions in his key and influential paper *The Republic of Science* (1962) [8]. In Britain, the *Haldane Principle* provided tremendous legitimacy to autonomous science organizations of research councils. In many ways, the foundation for a science-driven or linear innovation model was laid by these post-war events and the movement towards open and autonomous science. Even leading economists such as Mansfield (1991) [9] argued for basic research and the way in which it contributed to industry and society. Various technocratic and intellectual voices upheld the importance of autonomous science and its organization, which in many ways defined the tacit, informal but very powerful science–society relationship or social contract. The contract gained legitimacy in the organization of public and private research laboratories, science councils, and academies. Actors in these institutions produced systematic knowledge and advanced the state of scientific knowledge yielding social benefits. It is for this reason that the state and government funded scientific research out of public interest but usually did not interfere with research autonomy. Scientific knowledge is managed by a peer system [10] (p. 138).

Open science has evolved as a movement that promotes scientific research data and advances systematic knowledge which is accessible by a wider society at all levels subject to certain peer-based institutional measures. There is a wide international recognition that open science is composed of some critical elements such as open data, open material, open source, open access, open peer review, and open educational resources in the interest of maintaining a healthy science–society relationship and its social contract. UNESCO's intervention in making public the Human Genome Project data is a particularly good example. For instance, the European Commission, since 2016, has prioritized open science along with open innovation to the world in its path to research, science, and innovation policy that aligns with an open digital and global environment. In addition, a recent report on *Science as an Open Enterprise* by the Royal Society of London (London) has attracted people's attention and emphasized that "open inquiry is at the heart of the scientific enterprise. Publication of scientific theories—and of the experimental and observational data on which they are based—permits others to identify errors, to support, reject or refine theories and to reuse data for further understanding and knowledge. Science's powerful capacity for self-correction comes from this openness to scrutiny and challenge" [11] (p. 7).

Data, information, and knowledge and their translations are fundamental to science and its relations with society as much as for open scientific research [3] (p. 14). However, this notion of openness is based on the premise that data, information, and knowledge are accessible, intelligible, and usable openly to scientists and members of society [3]. With this overarching ideal, international regimes such as UNESCO and other agencies govern and sustain open science for the benefit of society with minimal relevant restrictions and regulations. One important insight that comes out of the paradigm of open and autonomous science is the factor of scientific progress and systematic knowledge advancement over the years. For instance, Alexander Fleming, who is credited with the discovery of Penicillin in 1928, did not willingly patent it and made its research results and science open for peer community and society. Similarly, there was a good deal of open science, information, and facts for discoveries such as the transistor, DNA, Double Helix, light bulb, among several others. Publishing of open science information in a peer-reviewed medium was freely available and used by the peer community leading to scientific progress. For instance, the Double Helix of Crick and Watson led to the future of molecular biology after their discovery.

Entering the third decade of the 21st century, this scientific social system and the social contract between science and society are undergoing major changes. It is threatened by various societal, market—economic, authoritarian—and global forces. In fact, the whole paradigm of open science and its social contract is challenged by various "enemies" or adversaries reminding us of the influential work by Karl Popper, *The Open Society and its Enemies* published in 1945 [12]. This classic was acclaimed as an important voice of democracy and free society. The era preceding this book witnessed the most devastating and horrible experiences the world has ever faced from the extremities of fascism and Nazism. In a different form and organization, open science today confronts new enemies and adversaries. There are numerous challenges to sustaining the ideals of the open science paradigm and particularly the science–society social contract which benefits society in varying ways. These challenges are coming, primarily, from (a) market-based privatized science, (b) 4.0 Industrial Revolution technologies, and (c) a new iron curtain obstructing the free flow of scientific data, information, and facts. The way restrictions on COVID-19 related scientific data and information led to conflicts between various governments and health agencies brings this issue into sharp focus. What impact will this have on our future sustainable science–society social contract [13]? These are some important issues that this article will discuss.

2. Challenges from Market-Oriented Privatized Science

Historically speaking, open science and its social contract with society at large are fundamentally based on the ideal of public good in science. This means that the scientific community making scientific discoveries and disseminating systematic knowledge via journals and publications is in the public domain for the welfare of society at large. This form of communication plays an important part in the progress of science and the advancement of systematic knowledge. With privatization and markets assuming a greater role in shaping economies, the commodification of knowledge and profit-making has assumed considerable significance. Public interest and market interest are based on two different opposing logics: public disclosure vs. normative research based on market standards and guiding them toward research commercialization [10]. With the rise of globalization and the monopolization of knowledge by multinational corporations, the tension between these two logics has sharply increased. The challenges from market-based privatized science manifest in different forms and organizations that threaten open science.

2.1. Threat to Basic Research and Public Good

Even though basic research is currently pursued and conducted by private corporations, science councils, and universities, there is a dramatic transformation of profit motives and steering by market forces that set priorities away from the public good of science. The way in which basic research was relatively open and driven by a curiosity for the advancement of knowledge has taken a big hit and is curtailed in large publicly funded science organizations such as CNRS (Paris, France), CSIRO (Canberra, Australia), NRC (Ottawa, Canada), CSIR (New Delhi, India, and Pretoria, South Africa) and several other countries and councils [14]. For instance, a Global Young Academy report on Canada drew attention to the long-term shift toward applied research (see ref. [15]). A survey of 1303 Canadian researchers showed that basic science dropped from 24% in 2006 to 1.6% in 2015. According to the American Association for Advanced of Science, the Trump administration's science budget proposal includes a 17% reduction in basic research funding (see ref. [16]). The US Information Technology and Innovation Foundation pointed out that federal basic research has been declining in 22 of 28 years. As a percentage of GDP, Federal Research has fallen from a high of 2.5% in 1964 to 0.61% in 2018 [17]. A recent book by David R. Johnson on the conflict between professional commercialization and academic science clearly illustrates how commercialism penetrates the structure of the American higher education system [18]. David believes that "the profit motive in science creates a situation where scientists place their own value and potential personal interests above the public interest." Such trends are quite evident in the OECD and other countries. Social safety nets, welfare, and health-related measures take care of poor people to a large extent in these industrially advanced countries. However, it has become a major problem across the developing world. Science as a public good is drastically curtailed in publicly funded agencies in the developing countries of Africa, Asia, and Latin America. In general, public-funded science in developing countries not only lags compared to those in developed countries but has over the years, declined in crucial sectors of public health, education, and food security as can be seen in the recent *UNESCO Science Report: Towards 2030* [19]. The space for the public good of science is rapidly shrinking in both developed and developing countries. The priority given to the science of privatization has begun to have a profound and serious impact on some developing countries. The recent problem of COVID-19 has clearly demonstrated this in the case of the health sector in developing countries and as well as in emerging economies like India, Mexico, South Africa, and Brazil. The main reason for the shrinking of the public good of science (and hence blockades for open science) is secrecy in science or a trend towards intellectual property rights.

2.2. Secrecy and Intellectual Property Rights (IPRs)

In every country, the state or government invests large sums of taxpayer money in research and development (R&D) and scientific research under the legitimation of the public good of science.

In addition to this funding, the private sources of funds for science have tremendously increased in every country over the last couple of decades. In the OECD, the USA, East Asian Dragons, and BRICS the private sources of total gross expenditure on research and development at a global level now constitute more than 78.13% (see refs. [20,21]). Given this privatized science, the drive towards secrecy in research and IPRs has come into sharp focus in TNCs and corporations. As noted above, even large science councils have over the years promoted IPRs in research. Hence, the most severe threat to open science comes from IPRs and secrecy in science. One is accepting that IPRs are a social reality and not at all rejecting them completely. What is being advocated here is creating a level playing field through science and innovation policy measures to sustain the space for the public good of science. In February 2004, 60 well-known academics, including 20 Nobel Prize winners, accused the US government of appointing experts with a lack of professional competence and conflicts of interest to various scientific committees. They asked the US Environmental Protection Agency to stop suppressing data related to public health and respect the disclosure of scientific information [22]. The Royal Society of London (Royal Society of London) pointed out in its report *Science as Open Enterprise* (2012) that "the economic reasons for universities to more strictly control intellectual property rights are doubtful. In the seven years from 2003/2004 to 2009/2010, the income of British universities has increased by 35%" [3] (p. 47). Corporates and TNCs have penetrated the elite universities in the USA with funding frontline scientific research and steering it towards a profit-oriented commercial end. In collaboration with Novartis in 1998, the University of California entered into an agreement for 25 billion USD. Novartis will have access to critical research information and will steer 33% of discoveries for years. Ignacio Chapela and David Quist, who mounted opposition to the collaboration and opposed this deal were persecuted. They had to leave their jobs for voicing criticism [22] (p.14.). This is not an isolated example. This practice of corporate industrial investments into academic universities in the USA, Europe, and other parts of East Asia has gained tremendous significance [23]. Traditional knowledge of yoga from India which has been freely disseminated the world over for centuries has now come under heavy attack from international corporates. The US Patent and Trademark Office is reported to have issued clearance for several yoga-related intellectual properties. Even the yoga mat has been patented [10].

2.3. Regulation of Science by Commercial Corporates

For a long time, scientific research and knowledge certification were based on peer evaluation and regulated by the scientific community. Publications in peer-reviewed journals played an important role in regulating scientific knowledge before reaching the public domain. Scientists traditionally selected their research problems based on scientific merits and research questions generated within the social institution of science. Much of the research priorities were determined by factors and entities within the scientific community. All over the world, several leading countries and their governments allocated large sums of money to scientific research but did not, in any big way, interfere with the day to day functioning of the research system. With the beginning of globalization, particularly since the 1990s, the relative freedom enjoyed by science institutions changed and science governance came to be encroached by several market stakeholders. The market-related priorities both in public science labs and universities transformed the social control of science operating in the institution of science. This practice has taken several forms and currently, even scientific communication is subjected to machine learning and automation. As Mirowski [24] drew our attention, the US Patent Office issued US Patent 9430468 entitled "Online Peer Review and Methods" in 2016. Elsevier is the owner of the patent. The core feature of these patents is the process of organizing and implementing peer review on computer programs. Another platform-based automatic peer review reported in recent years is a natural language generator that can generate credible research reports (see ref. [25]). New technology, which is being utilized in detecting fraud, copying, plagiarism, and scanning research theses for spelling and other constructive purposes is very welcome. However, AI and machine learning techniques being used for what Mirowski [24] calls "platform capitalism" in the name of open science, moving towards commercialism, monopoly, and profit-making are destroying the conventional science and society relationship. Advances in health-related biomedical research are no longer vetted by a peer-based system by the scientific community, but by different corporate partners in scientific projects. For instance, during April–June 2020, one can see how scientific developments and research processes progressing in COVID-19 related vaccines are being reported in mass media and leading newspapers much before they find their way into peer-reviewed science journals.

One can witness several disruptive practices in the priorities of scientific research. The *Social Health-Related Science* project of the British Economic and Social Research Council (ESRC) concluded that 90% of the world's health research is spent on issues that affect only 10% of the world's population (ESRC [26]). In the 1990s, some developing countries such as India opposed Monsanto's "terminator gene". Such practices are quite widespread and rampant, clearly showing how scientific research guides the maximization of profits. There are several examples in the case of leading US universities on how big enterprises and business firms have penetrated the academic research system. For example, the Whitehead Institute of Biological Sciences has invested a lot of money in the Massachusetts Institute of Technology since the 1990s, and it is located on the MIT campus. This type of transformation in the institution of science is quite visible in several leading *Ivy League* universities in the USA and leading universities in Europe such as Cambridge and Oxford. The radical change in the academic culture and institutions of higher learning is rapidly transforming the traditional social contract between science and society [27].

The commercialization of research has become an inseparable part of university academic science, academic policies, teaching, and research. Before the 1990s, there were no similar concepts to the "entrepreneurial university", but as Etzkowitz [28] predicted, this concept spread like wildfire. For example, the National University of Singapore "aspires to become an important community for academics, researchers, employees, students and alumni, who are committed to a better world in a spirit of innovation and progress" (see ref. [29]). All major universities institutionalize the concept of entrepreneurial university entities in some form. The science park and innovation park have now become part of traditional universities. TNCs and corporates have established various commercial collaborative programs and joint ventures with universities, not for advancing knowledge but for profiting from university-based academic science. The St. John's Innovation Center and Incubator at Cambridge University, the Tuspark at Beijing's Tsinghua University, and the Technology Park at the Indian Institute of Technology in Madras are some examples. Earlier, multinational companies and universities used to keep a certain distance. One could easily distinguish organizational cultures and goals distinctly. However, the last couple of decades witnessed tremendous close collaborations and partnerships between academia and industry. The Novartis case noted above at the University of California is not an isolated case. One can recall the famous development at the beginning of the biotechnology revolution. The scientific research of Herbert W. Boyer and Stanley Cohen led to recombinant DNA technology and ultimately led to the establishment of the biotechnology company Genentech (1976), which was a "sensational" company on the American Stock Exchange. Imperial Innovations is a UK technology commercialization and investment company, which formed in 1986 as a department of Imperial College London. Since 2006, shares of the company have been traded on the London Stock Exchange (see ref. [30]). The IP Group in the UK, an intellectual property commercialization company, has invested large sums of money at Princeton University, John Hopkins, University of Pennsylvania, Yale, and Washington University. In 2001, the IP Group invested 30 million USD to build a chemistry building at the University of Oxford. Their main purpose is to acquire shares in start-ups established around the intellectual property of the Department of Chemistry (see ref. [31]). Allied Minds, another Boston based start-up investment firm has links with 34 US universities. Similar is the case with Tsinghua University in China. Academic institutions, which were quite removed from the stock exchange in the past, are now entering into the commercial and trading domain in some form. This is indeed a huge change in the past 15 years.

3. Industrial Revolution 4.0 and Its Challenges for Sustainability

In the last decade, if there is one important science, technology, and innovation policy discourse that has caught the imagination of world leaders and governments alike, it is the perspective and strategy of the Fourth Industrial Revolution or IR 4.0 technologies. After the First, Second, and Third Industrial Revolutions, respectively, we are now entering into yet another paradigm of scientific and technological transformation characterized as the Fourth Industrial Revolution. It is the fusion of AI, Robotics, IoT (Internet of Things), and physical and biological sciences. Sundar Pichai, the Chief of Google and Alphabet at Davos observed that "the combination of artificial intelligence and quantum computing will help us solve some of the biggest problems we see ... When I look to the future, I will say: 'How do we promote improvements?'—quantum will be one of the tools in our arsenal" [32]. In a similar vein, IBM chief Gini Rometty in 2019 at Davos observed that in the coming decades "AI will completely transform almost every business on the planet. The shift to the era of cognitive enterprise will be a multi-step journey but it is one that has the potential to create massive value for the business and drive the next phase of competitive advantage" (see ref. [33]). Similar foresight was expressed by most leading corporations and influential leaders. Despite the euphoria over the Fourth Industrial Revolution and its optimistic view as a harbinger of a new era, clear signals of technological threat were expressed. Professor Klaus Schwab, the founder and executive chairman of the World Economic Forum, clearly stated his vision of industry 4.0 for our society in the book, *The Fourth Industrial Revolution*.

> The previous industrial revolution liberated humans from the power of animals, made mass production possible, and brought digital capabilities to billions of people. However, this fourth industrial revolution is fundamentally different from this. It is characterized by a series of new technologies that merge the physical world, digital world and biological world, affect all disciplines, economies and industries, and even challenge the meaning of mankind. The resulting changes and chaos means that we are living in an era full of hope and great danger ... Organizations may not be able to adapt; the government may not be able to use and supervise new technologies to obtain its benefits; the transfer of power will create new major security issues; Inequality may increase; societies fragment [34].

Despite Schwab's warnings of "great peril" for society and that "inequality may grow; and societies fragment", techno-scientific innovations of industry 4.0 were accepted as the most important agenda of science, technology, and innovation policies by each and every country on the globe. More than anything else, techno-science frontiers associated with industry 4.0 were viewed as a "technological fix" for innumerable problems. Techno-science signifies how basic science has so much become an integral part of technology development. One may see the fusion in big data science, big data analytics, AI, robotics, IoT, among other advancements in the present day knowledge frontiers. In other words, there is a sense of technological determinism that dramatically transforms the way we live, move, and help to create new entities in this physical environment. We will have to learn to adapt to this technological change as it also has solutions to various problems. There is indeed a strong belief in the perspective that technology is uncontrollable and unpredictable by humans, causing people to feel helpless in front of the explosion of this new era 4.0 techno-scientific world. Associated with this is the recognition that technology is autonomous (and in many ways neutral) in its trajectory and that we in our society need to adapt to these changing techno-scientific world views (see refs. [35,36]). The technological deterministic views associated with the scientific and technological advances of industry 4.0 pose one of the biggest challenges to the science–society social relationship. As Yuval Noah Harari in his recent book *Homo Deus: A Brief History of Tomorrow* (2016) draws our attention [37], the advances in the techno-sciences of 4.0 are likely to create a ripple effect on society and economy against inclusive innovation. A "new cognitive violence" is likely to be unleashed on our society which is already being felt in developed as well as developing societies in livelihoods and the nature of work. In many ways, there are innumerable examples to demonstrate how the traditional and existing science–society contract based on inclusive science and technology and the public good of science is being disrupted in favor of the "one-dimensional" view of creating wealth and power in national economies through advances in AI, robotics, quantum, and several techno-sciences associated with industry 4.0.

Mega-corporations such as Google, Facebook, IBM, Microsoft, Amazon, Alibaba, and Didi among several others that dominate in the 4.0 techno-sciences have already unleashed profit-oriented consumerism, labor-saving, and dehumanizing surveillance devices (see ref. [38]). ImageNet is the world's largest image recognition database. As we all know, it is a visual object recognition tool designed for large companies such as Amazon and Facebook. ImageNet was established by computer scientists at Stanford University and Princeton University in the United States and is considered the beginning of the deep learning revolution (see ref. [39]). One can see the way technological determinism plays out in its varying forms. For instance, the whole science and innovation policy focus is being laid on AI mimesis that is the ability of machines to perform tasks that normally require human intelligence. This is likely to not only render the loss of human work and livelihood but will also dehumanize or alienate society and people. Face recognition technologies have already led to the threatening of privacy and human rights (see ref. [40]). The most devastating impact of science and technologies behind the Fourth Industrial Revolution is expressed by the guru of Davos and one of the pioneers of this phase of industrial trajectory, Klaus Schwab.

> In the final analysis, everything comes down to people and values. We need to shape a future that works for all of us by putting people first and empowering them. The Fourth Industrial Revolution, in its most pessimistic and inhumane form, may indeed be possible to "robotize" human beings, thereby depriving us of our hearts (Schwab [34]).

The International Labor Organization estimates that 70% of Vietnam's jobs are likely to be replaced by artificial intelligence machines. The report also points out a series of jobs that are vulnerable to current or future technological automation. The International Labor Organization cited in a research report that 47% of American jobs, 36% of British jobs, and other figures ranging from 55% in Uzbekistan to 86% in Ethiopia, are at risk. Another major development agency (UNDP) report on Asia has drawn attention to an unprecedented risk of automation in East Asian "Tigers" (Hong Kong, Singapore, South Korea, and Taiwan) and China, in addition to countries such as Malaysia, Vietnam, and Thailand. It is established in the field of automation in the manufacturing industry, including electronic technology, automobiles, and clothing that Robotic Process Automation (RPA) threatens the service industry. These industries have promoted GDP and unemployment in India and the Philippines [41] (pp. 22–24). Besides work and job losses, there is the whole issue of the ethics of AI-related technologies and their operation in society. Even before regulatory agencies and governments realize the social implications, a number of ethics-related problems have come into sharp focus. Issues of ethical lapses in the use of AI-related technologies have been raised from different quarters related to the accuracy of information and data being used as well as privacy, transparency, accountability for unfair trading, among other related issues. Industry 4.0 scientific and technological advances have generated much hype, undermining the inclusive science and innovation underlying the science and society social contract. Although big companies promise to create a world of efficiency, productivity, and a new economic miracle, these tools promote and amplify concerns about technology-driven unemployment and overall social inequality. Globalization has already created a gulf between the rich and poor within and across countries (Piketty [42]). This will be further accentuated with the coming of a new industrial revolution.

4. Democratic Deficit and New Iron Curtain for Free Flow of Information

Robert Merton's [4,5] normative structure of science and his insights calling for a democratic social order for the advancement of systematic knowledge is one of the foundational features of the science and society social contract and that of open science. "In a modern totalitarian society, anti-rationalism and centralized institutional control have restricted the scope of scientific activities" [5] (p. 78). As Everett Mendelsohn [43] (pp. 269–289) points out, Merton's focus on the critical factor of open science was in fact rooted in Nazism and the elimination of some elite scientists in Germany as much as it was due to the extremities of Soviet-style communism. This perspective of science and democracy came into sharp focus in the last several decades whenever science and its free flow of information and facts came under severe threat [11]. The understanding of science and democracy also stems from the views and concepts of "civic science" or the public's understanding of science. The Royal Society promotes the public understanding of science, which is one of its main activities (see ref. [44]).

As Alan Irwin [45] observes, citizen science is "the concept of developing scientific citizenship, which foreshadows the necessity of opening up science and science policy processes to the public." Even though citizens could systematically investigate independently, in the end, research results will have to be peer-reviewed by the science community. Even in disputes and scientific controversies that land up in courts, there are technical evaluation committees set up to adjudicate who represents the science community. As Brancom and Rosenberg [11] point out, science and democracy share the same values. The foundation of a democratic society is public debate, free flow of information, mutual respect, and the key role of investigation and evidence. As Milovsky [24] (p. 176) pointed out, "since 1980, the situation has undergone another major change, from a science mainly funded by the military and the state-sponsored science to a science primarily subordinate to market considerations, organized by corporate patrons and academic contractors" [24] (pp. 171–203). The way in which the science and society social contract and the social institution of science have suffered is evident from the recent developments in the USA over COVID-19 dealings. As the recent Brookings institution reports and draws attention (see ref. [46]), destroying trust in science has left America vulnerable to the COVID-19 pandemic. It points out, "science has become another Trump target. Whether it is suspicion of climate change, support for cuts in basic research funding, or hostility to general universities, they have trained their rhetorical weapons on the scientific community with devastating impact." As early as 30 November 2016, more than 2300 scientists (including 22 Nobel Prize winners) wrote to the Trump administration and Congress to take actions in four areas to create: (a) a strong and open scientific culture, (b) ensure public safeguards of clean air grounded in science, (c) adhere to high standards of scientific integrity and independence, and (d) sufficient scientific resources (see ref. [47]). It is not accidental that the OECD's policy response to COVID-19 proposed three messages on "why open science is important to fight against COVID-19". These are:

- In a global emergency such as the Coronavirus (COVID-19) pandemic, open science policies can remove barriers to the free flow of research data and ideas, thereby accelerating the pace of research that is critical to combating the disease.
- Although the global sharing and collaboration of research data has reached an unprecedented level, challenges remain. Trust in at least some data is relatively low, and outstanding issues include the lack of specific standards, coordination and interoperability, as well as data quality and interpretation.
- In order to strengthen the contribution of open science to COVID-19 response measures, decision makers need to ensure appropriate data management models, interoperable standards, sustainable data sharing agreements involving the public sector, private sector and civil society, incentives, sustainable infrastructure, human and institutional capabilities and mechanisms to obtain data across borders [48].

As is widely known and publicized in the scientific and general media, there is a critical discourse emerging on the way in which scientific information and research results on COVID-19 are being regulated in China. There is international concern as reported in the leading British science journal, *Nature* (15 April 2020) that "the Chinese government has started asserting strict control over COVID-19 research findings. Over the past two months, it appears to have quietly introduced policies that require scientists to get approval to publish... at least two Chinese universities have posted online stating that research on the source of the virus needs to be approved by the university's academic committee and the Ministry of Science and Technology, (MOST) or Ministry of Education before being submitted for publication." A coalition of over 60 countries has asked for an independent inquiry into how the virus emerged and spread in Wuhan. In fact, Chinese President Xi Jinping, in response to the global discourse on COVID-19, "supports a comprehensive review of the global response to the COVID-19 pandemic led by the World Health Organization (WHO) after the virus that causes the disease is brought under control" (see ref. [49]). Beyond the political standpoints and conflicts over COVID-19 and its origins, open science communication has become a major victim. It is not surprising that the global network of science's collaboration on sharing research results on this pandemic and containing its spread through the World Health Organization has come into sharp focus.

In January 2020, 117 organizations, including journals, funding agencies, and the Centers for Disease Control, signed a statement promising to provide immediate and open access to peer-reviewed publications at least during the outbreak of the pandemic. The print server provides the research results and immediately shares them with the World Health Organization. This was followed by the public health emergency COVID-19 initiative launched by 12 countries in March, calling for open access to publications and machine-readable data related to COVID-19. Subsequently, an international alliance of scientists, lawyers, and technology companies initiated the COVID pledge in April 2020 to provide all intellectual property (IP) under its control (see ref. [49]). International collaboration, networking of science communication based on empirical research on COVID-19 health issues, and above all, free flow of information have become critical factors in finding a solution to this global problem. Secrecy and suppressing data and information on the growing pandemic problem have become a major contention amongst countries. International agencies are urgently calling the attention of countries and governments towards open science. A major policy thrust for open science from OECD has now come out with certain recommendations for actions during COVID-19 crisis [48].

- Develop a data governance model to allow open research data by default while protecting personal privacy.
- Provide a regulatory framework to enable interoperability within large electronic health record providers, patient intermediary exchanges, and peer-to-peer direct exchange networks.
- Public actors, private actors, and civil society work together to formulate and/or clarify a governance framework in order to credibly reuse privately held research data for public interest.
- Clarify incentives and rewards for researchers, and require immediate disclosure of data, software, and protocols for release. Institutions and national policies should address the issues of recognition and cultural/structural barriers between data providers and transform the system into a culture based on sharing.
- Securing adequate infrastructure (including data and software repositories, computational infrastructure, and digital collaboration platforms) to allow for recurrent occurrences of emergency situations.
- Ensure sufficient infrastructure (including data and software repositories, computing infrastructure, and digital collaboration platforms) to allow repeated emergencies.
- Ensure that there is sufficient human capital and institutional capacity to manage, create, curate and reuse research data.
- Enabling access to sensitive research data across borders on a more restricted basis in secure environments. This primarily concerns clinical data which may not be allowed to leave the original repository, but could potentially be accessed by mobile algorithms which could use the data to answer specific research questions [48].

These international developments and voices raised in the last few years are due to an increasing threat to open science and communication from big transnational corporations and of late from some authoritarian regimes. A major threat to open science has come from what has come to be known as platform capitalism which refers to the activities of companies such as Google, Facebook, Apple, Microsoft, Uber, and Airbnb operating as platforms. They are monopolizing data of all sorts to use in their commercial and corporate affairs and trading. British Newspaper, *The Guardian*, observes "data is the new oil. Just as John D Rockefeller's Standard Oil swept the spoils of the—initial competitive—oil rush, the future of the internet will be shaped by a handful few tech titans, including Google, Apple, Facebook, Amazon and their Chinese equivalents Tencent, Alibaba, and Baidu" (see ref. [50]). As Yuval Noah Harari pointed out, "those who control the data control the future not just of humanity, but the future of life itself. The rise of machine learning and deep learning, smart artificial intelligence software can mine huge sets of data and find meaningful patterns that would go unnoticed to the biologically limited minds and human beings" (see ref. [51]). Besides, there are leading big data and data science firms such as IBM Watson which are in the business of biomedical data. These firms systematically collect data and information on bioinformatics, clinical informatics, imaging informatics, and public health informatics. The trend of big data and data science poses a big challenge when personal and publicly funded health data is appropriated under public–private partnership arrangements. In most cases, the whole ethical, personal, and privacy issues are either glossed over or regulatory measures are insufficient to protect the fundamental rights of persons. This data, which becomes an important resource, is used by companies to create value without providing people with reasonable compensation. Regulating and sustaining a healthy science and society relationship is a big challenge that is being debated by the science community and international agencies such as UNESCO.

5. Concluding Remarks

Science as a social institution, that has been governed and controlled by the science community for the last three hundred years, has come under severe threat in the 21st century. Open science as opposed to intellectual property rights, science for public good as opposed to market good, peer review, and the prominence attached to open publications, that characterize the science and society social contract, are rapidly disintegrating. The social institution of science has now come to confront several enemies that stand to threaten its character of knowledge as a public good and the ethos underlying the science–society social contract. Our past experience shows that open knowledge has its own advantages because it helps solve many important practical problems, and it also helps raise the threshold and paradigm of new knowledge [10]. This change is no less than the "Cultural Revolution" in science. As demonstrated in this essay, the main threat to open science is unleashed by rapidly growing profit-oriented market-based privatized science, unethical and unregulated techno-sciences of the Fourth Industrial Revolution, and the new "iron curtain" of the free flow of scientific data and information. This last feature assumes enormous significance in the current context of the COVID-19 pandemic that has spread like wildfire. The very success in finding a solution to this problem depends on institutional structures and nation-states that facilitate the free flow of scientific information and data.

Social change and social transformations are part of our evolutionary life-world in society. Science, technology, and their progress are very much part of this transformation. In view of this understanding, some institutional safeguards for managing intellectual property must be established to maintain the free flow of scientific information and data, so as not to hinder the further development of science. Privatizing basic knowledge is a danger to scientific and technological progress [52] (p. 356). The dangers of some crucial technologies of nuclear, telecom, and biological research are currently regulated by various regimes such as Nuclear Suppliers Group, International Telecommunications Union, and RNA and DNA regulatory committees in various countries. Hence, there is a good reason to adopt appropriate regulatory regimes in the case of the most disruptive industry 4.0 technologies such as robotics, AI, and machine learning, among others, which threaten livelihoods and are likely to infuse alienation in society. We have witnessed earlier industrial revolutions but this current one is radically different in pace, speed, and impact. It entails several damaging features for a sustainable society if not regulated or socially controlled. Some cases, which entail ethical and dangerous signals, call for international regimes of regulation. In some others, national governments will have to deal case by case as relevant and appropriate to their respective socio-economic milieus.

From the perspective of science and technology policies, as Pandey et.al. [53] and Bijker [54] argue, we need to bring in various policy measures on responsible research and innovation (RRI) to accommodate uncertainty and augmented dangers. As Pandey et al. [53] clarified, from the key insights of previously controversial technologies, as well as insights into the uncertainties and lack of knowledge related to the future, RRI stipulates that research and innovation should go through a process of anticipation and reflection [53] (p. 217). In some critical technologies which threaten life (COVID-19 for instance) and endanger sustenance (for instance green and low carbon technologies), there is a need for invoking institutional measures of what has come to be known as "Scientific Commons". This is particularly crucial for poor developing countries. In some other cases of new technologies and in the biomedical domain, costly therapies have become highly restrictive and prohibitive due to strong IPRs, there is a need to extend the scope and umbrella of access through some policy measures such as "Compulsory Licensing" arrangements. In the field of climate change, there is already a concept of common but differentiated responsibilities. This concept is based on the historical responsibilities of countries and their different capabilities in responding to climate change. Thus, what is being argued is for appropriate science and innovation policy measures to create a level playing field between open science and market-oriented privatized science. As argued elsewhere [10], globalization has become a reality in our society, economy, and daily life. How can we save scientific institutions from being completely replaced by globalized economic and market-oriented forces? As Amartya Sen has correctly observed from an economic perspective, we need to develop mechanisms to maintain a level playing field between public good and market good. We need to develop institutional mechanisms and policy tools to "make globalization work for all, not for the few." Professor Amartya Sen discussed this with Joseph Stiglitz and Dr. Manmohan Singh at the FICCI seminar held in New Delhi around 2003.

In the post-war era, developing countries benefitted immensely from the liberal, democratic global science institutions which were governed by the ethos of open science and the science–society social contract. Industrially advanced countries invested large sums of money in academic science and developed world-class universities. In the post-COVID-19 phase, economically battered economies of industrially advanced countries are more likely to create difficult entry barriers and access to these prestigious institutions. This global window of opportunity for research access which operates with the unfettered ethos of open science will be severely restricted. This is due to the increasing commodification of knowledge and market-driven profit-oriented global R&D in industry 4.0 technologies and biomedical techno-sciences particularly. The technological imperialism unleashed by industry 4.0 technologies of AI and automation has already rendered tens of thousands of workers jobless in some South Asian and East Asian economies (see ref. [55]). With low and stagnant investments in higher education and science and technology research in the last decade, the technological dependency of poor developing countries on advanced and emerging economies will increase rapidly. Some clear signals are already evident in the case of some African countries such as Angola, Sudan, Congo, Zambia, among others, which continue to experience acute problems of food and health security. Some developing countries in Latin America, Asia, Africa invest a meager sum of 0.1% to 0.5% of their GDP on science and technology (S&T) research, falling short of a magic figure of at least 1% of GDP recommended by UNESCO [56]. They must evolve new endogenous science, technology, and innovation policy strategies to not only sustain the onslaught of industry 4.0 technologies but safeguard livelihoods through basic research in agriculture and health sciences. Basic research and public spending on S&T are not a luxury but an essential factor of development and sustainable strategy in the future of the developing world. One is aware that developing countries are not homogenous. One is referring to poor developing countries according to the UN index, excluding those emerging economies such as BRICS. China and to a lesser extent India are good examples of such economies averting the syndrome of dependence in the crucial sectors of food, health, and other sectors through investments in science and technology.

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Open science practices in higher education: Discussion of survey results from research and teaching staff in Germany

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Aspects of open science and scholarly practices are often discussed with a focus on research and research dissemination processes. There is currently less discussion on open science and its influence on learning and teaching in higher education, and reversely. This paper discusses open science in relation to educational practices and resources and reports on a study to investigate current educational practices from the perspective of open science. We argue that offering students opportunities via open educational practices raises their awareness of future open science goals and teaches them the skills needed to reach those goals. We present online survey results from 210 participants with teaching responsibility at higher education institutions in Germany. While some of them try to establish more open learning and teaching settings, most respondents apply rather traditional ways of learning and teaching. 60% do not use open educational resources – many have not even heard of them – nor do they make their courses open for an online audience. Participants' priority lies in resource accuracy and quality and we still see a gap between the benefit of open practices and their practicability and applicability. The paper contributes to the general discussion of open practices in higher education by looking at open science practices and their adaptation to the learning and teaching environment. It formulates recommendations for improvements of open practice support and infrastructure.

Keywords: Open educational resources, open science, open education, survey

1. Introduction

Open science and open education are strongly connected through the concept of 'openness', but they approach this concept from different perspectives: Open science – here we mean as well open research, i.e. referring to natural sciences, social sciences and humanities likewise – mostly refers to research and researchers as

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well as aspects connected to the scientific enterprise such as scientific communities, publications, and research impact (Bartling & Friesike, 2014a; Herb, 2015). In contrast, open education is concerned with open strategies and approaches to learning and teaching in various settings like schools, higher education, vocational education, informal learning. Open educational resources is a key element of open education and well explored by the literature (Hylén et al., 2012). Research most often discuss openness in either science or education without referring to the interrelation of both fields, specifically in higher education environments where a large number of employees are concerned with both, research as well as learning and teaching. Moreover, discussions within both movements, openness in science and education, mostly concentrate on how to facilitate and secure access to their products, such as scientific publications and open educational resources. This results in countless open access initiatives, guidelines, and progress reports. Those activities overlook an important and integral part on the way to more openness, which is that open practices include more than open access to final products of science and education. Our goal is to understand how educational practices in higher education reflect diverse forms of practices discussed within the open science movement, which might foster a better integration of open science practices of future researchers.

We conducted a study, which used a quantitative online survey to ask academic staff teaching at higher education institutions in Germany about their use of digital media, tools and OER, and their teaching practices. Results consider practices of teaching staff including resources, technologies and activities that relate to currently discussed aspects of open science. The leading research question is:

> Which open science related practices are currently applied in German higher education?

In this paper, we briefly introduce aspects of open science and open education before we lay out opportunities of open practices. Afterwards, we report on our quantitative survey that provides a view on current practices of teachers. We summarize the survey findings and compare them to similar studies before we draw conclusions.

2. Aspects of open science

Open science or open research stands for a movement which suggests openness in all phases of the research lifecycle (European Union, 2016; Förstner et al., 2011). It considers not only the use of new technologies in areas like content access, shared ideas and collaboration, but advances further discourses, some of which stand for a radical change in research behaviour, like open peer review (Ross-Hellauer, 2017), open grant writing and open evaluation. As such, in open science researchers move from publishing as early as possible to sharing as early as possible (European Union, 2016). Researchers have even mentioned a second "scientific revolution" (Bartling & Friesike, 2014b; Friesike et al., 2015; Nielsen, 2013). Researchers and stakeholders of the scientific enterprise, such as funders and institutions of higher education have established proper infrastructures for making research more open, like open access repositories and professional research data archiving centres. Herewith, libraries and information infrastructures centres see a change to position themselves to a new area of responsibility (Fecher et al., 2017; Fender, 2015). There seems to be a tendency towards open access publishing (Bosman & Kramer, 2018), with publishers offering more open access options and funders supporting open access publishing. Recent practices and business models within the publishing landscape have their potential and drawbacks, and are discussed controversially by different authors, often debating the affordance of open access (Green, 2019). This discussion is beyond the scope of this paper.

Besides infrastructure development, large initiatives have emerged to support the Open Science moment and developed guidelines to apply open practices and guarantee high quality of open data. One such initiative is a larger EU project named FOSTER (fosteropenscience.eu) that offers courses and online materials for researchers to learn about open practices. Another one is the Go FAIR initiative (go-fair.org), which suggests that any open data should be findable, accessible, interoperable and reusable (Wilkinson et al., 2016). Its concrete application is relevant for data producers such as researchers and metadata editors and for infrastructure developers that give access to this data.

Larger bibliometric studies (Piwowar et al., 2018) analyse open access publishing and show a positive trend – however there are still great differences across disciplines (Bambey, 2016).

Other recent studies aim at finding explicit explanations for researchers open practice behaviour. such as the study by Moksness and Olsen that shows attitudes and social norms as predictor for publishing open access (Moksness & Olsen, 2017). Other surveys showed that external factors like a researcher's institution or their personality influence the adoption of sharing one's research data openly (Kim & Nah, 2018; Kim & Stanton, 2016; Linek et al., 2017). Moreover, researchers define "openness" in different ways, which influence their practices (Levin et al., 2016), specifically in relation to their research impact in society and good research practices guaranteeing research quality (Grubb et al., 2011). However, other studies show that some researchers are still sceptical of sharing their data (Blahous et al., 2015). One reason for this might be the lack of incentives and resources, as well as a not so well established reputation of open data usage. A recent survey showed that attitudes differ with regard to how open peer reviewing should be handled (Ross-Hellauer et al., 2017). Some researchers prefer an open process where reviews are accessible immediately, others want reviews to be accessible after paper acceptance. Another positive influencing factor of adopting open science practices seems to be open science policies (Levin et al., 2016), framed for example by research funders and journal publishers that now want researchers to share their data. Despite diverse attitude and recent practices among researchers with regard to open practices, most researchers show a positive attitude towards the goals of open science as the study of Kramer and Bosman (Kramer & Bosman, 2016) showed, where over 80 percent of the respondents agreed to the goals of open science.

3. Aspects of open education

Open education shall decrease learning inequalities and support lifelong learning (Blessinger & Bliss, 2016a; UNESCO, 2012). A core element of open education is open educational resources (OER). There is a common understanding of the nature of open educational resources – although there might be some disagreement on best practices and types of licensing to adopt. OER are educational resources and materials that users are able to retain, reuse, revise, remix and redistribute (Wiley et al., 2014). OER include all kinds of educational resources, including learning material, tools and software. "Access is fundamental to open education. [However] Open education goes beyond access" (Blessinger & Bliss, 2016a, pp. 13–14), practices need to include "the construction of new pedagogies and learning activities" (Kaatrakoski et al., 2016). Increasing the use of OER and at the same time adapting open pedagogies leads to an increase in open educational practices (Albion et al., 2017; Ehlers & Stracke, 2012) and fosters open education. Cronin (Cronin, 2017) expands this definition: "OEP ... [are] collaborative practices that include the creation, use, and reuse of OER, as well as pedagogical practices employing participatory technologies and social networks for interaction, peer-learning, knowledge creation, and empowerment of learners." Similarly to discussion on OER and aspects of open practices, our study asked about the use and creation of OER and additional open practices referring to derived scenarios in science and education.

Studies on open education practices focus on applying OER (Bossu et al., 2013; Boston Consulting Group, 2013a) or open textbooks (Seaman & Seaman, 2018), or discuss any influencing factors like policies and their potential to foster OER use and creation (Bossu & Stagg, 2018; Cox & Trotter, 2016). Researchers see potential in current initiatives, but see a need for improvements (Stagg & Bossu, 2016; Udas et al., 2016). Kaatrakoski et al. (2016) still see tensions in practices between individual's needs and institutional policies, educators' amount of teaching responsibility and institutional accountability, and cost efficiency and learning objectives. In her qualitative study, Cronin describes four levels by which educators can be distinguished with regard to their open practices: macro (will I share openly?), meso (who will I share with?), micro (who will I share as), and nano (will I share this) (Cronin, 2017). Cronin states that educators are influenced in adopting open practices by diverse factors such as the use and creation of OER that has a positive influence (compare (Wiley, 2015)). Reversely, open practices like networking foster the awareness or OER (Cronin, 2017).

Stagg (2014) discusses not only open educational resources use, but practices like enabling an open environment for students (discussion options, options to share ideas and one's work), and formal credit, meaning that students' open behaviour find its way into the formal assessment process. With regard to open pedagogies, research discusses concepts of research-oriented learning, with forms of openness referring levels of student autonomy (Brew, 2013; Heck & Heudorfer, 2018). In this study, our understanding of practices refers to activities, behaviours and attitudes of teachers that contribute to more or less open learning and teaching environments, similar to prior discussions (Stagg, 2014; Väänänen & Peltonen, 2016), with the aim to get first insights into teachers' practices and their levels of openness.

3.1. Adopting open practices in teaching and learning

Open practices in science and in education seem to share some commonalities. Väänänen and Peltonen (2016), for example, draw a connection between the concept of openness in research, learning and teaching in higher education. In higher education where research and learning meets, an open environment including access to research and OER, fosters open science. Moreover, the authors state that fostering competitive research "while preserving accessible and shared materials and knowledge is essential to OER" (Väänänen & Peltonen, 2016). So, the higher education field seems to be an environment where open science and open educational practices can meet on shared commonalities of the concept of openness. More explicitly, open science and open education are related through their actors such as researchers in higher education, who not only do research, but teaching as well. The current version of the open science training book ("Open Science Training Handbook") summarises this fact: "In many cases open educational resources are built upon research findings. If you are an Open Science practitioner it makes sense that your educational resources maintain the level of openness of your research".

Figure 1 was developed to show some key components of openness in open science that overlap with open educational practices scenarios. Moreover, those aspects could also be more broadly related to research and education practices.

One component are tools, i.e. systems and services – mostly digital – that support communication and collaboration in science. Openness in this sense might refer to a tool's accessibility, its costs or its compatibility with other services. Many researchers refer to open source tools and software as services that are accessible, modifiable and have freely (re)-usable code ("Open Science Training Handbook"). Thus, open source research tools are easy and affordable to use for learning and teaching and can facilitate access to research data and sources for learners.

The second component are activities such as personal behaviour and interactions of researchers like communication and collaboration in research communities. Activities can be visible to all, restricted to specific groups, or closed like blind peer review processes. Adapting those to teaching and learning scenarios, activities can refer to either the behaviour of teachers or the behaviour of learners. Relevant aspects for learners are options to create and share own content, and to discuss with peers.

The third component are resources such as data, books or scientific articles. Scientific resources freely available for everyone, or even openly licensed, is one goal

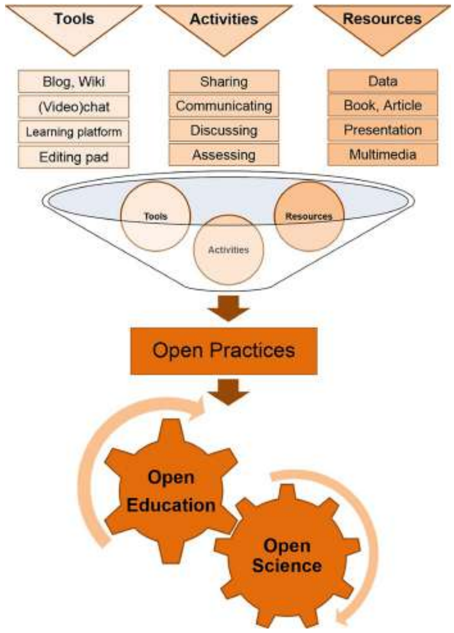

Fig. 1. Open practices relevant for research and education.

of open science supporters. Similarly, freely available and openly licensed educational resources like open educational resources are the goal of the open education movement. They allow learners fully and non-restricted (no costs, no restricting file formats) access to relevant learning materials. Those three aspects, which are discussed with focus on open science practices in research, and with focus on open resources and pedagogy in education informed our survey.

4. Survey on open practices

We conducted an online survey to investigate the status openness in higher education based on components of openness in open science that overlap with open educational practices scenarios (Fig. 1). We did not ask about any pedagogical designs like research-oriented learning or other concept applied in learning and teaching scenarios, but focused on practical implementations of aspects of open science.

5. Method

This is an explorative study that aimed at questioning current issues and ideas to implement open science practices in education. The target participants were any academics, professionals and researchers with teaching responsibility at German higher education institutions, including universities and universities of applied sciences. As higher education systems and educational roles differ globally, we did not aim at designing this survey to be used internationally. However, we think that the design of the contextual questions (in contract to demographic questions) is adaptable and a comparative study in other countries would be beneficial.

Regarding our study, we aimed at doing a purposive sampling and involving people from groups and communities that engage in discussions and activities about open science and open education. To reach them we sent the survey to diverse institutional-internal and external mailing lists and via personal contacts. We also included mailing lists that were discipline-based, derived from higher education and higher education didactic communities as well as lists from open science, Science 2.0 and open educational resources communities. Additionally, personal e-mails were sent to presidents and contact persons from those communities, and Twitter was used to disseminate the survey.

We collected data anonymously and survey participation was voluntary. Thus, we did not seek approval by an ethics committee. Potential participants were informed about the study, data usage and its goals on the online survey landing page. They were informed that they give consent for their anonymous data being used for scientific purposes when starting the online survey. The survey was online from February 6 to March 3, 2017.

The survey structure and data is openly available (Heck et al., 2017a; 2017b). It includes 20 topical questions which were separated into five major topics: demographics (4 questions), material used in courses (4 questions), open educational resources awareness, usage and development (6 questions), collaborative tools used in courses (1 question), assessment and participation options (5 questions). The question types differed, with mostly single choice questions, multiple choice where applicable (choice of applied tools), and 5-point-likert scale when participants had to rate the importance of resource characteristics (Fig. 2). We offered a comment field when participants clicked the NO-answer and at the end of the survey. As well, participants had the option to add additional answers, e.g. tools they use that we did not list.

Questions on OER regarding use and creation of OER and reasons for this behaviour. Data from earlier studies revealed that academics were confused about the proper definition of OER. Some seemed to understand OER as free resources, or only refer to open source software (Seaman & Seaman, 2018). Other studies (Seaman & Seaman, 2018) decided to give a broad explanation of OER, avoiding details to not tempt the participant to claim "awareness". However, there is a danger of having a bias when giving an explanation. We decided not to give an explanation to participants about the definition of OER, but to keep this question simple. We assume that either someone does or does not know about OER. If they had not heard of the term before, they do not properly use OER (at least not consciously) or create them.

Demographic questions asked about the current professional position, the discipline, year of birth and gender. The classification of research disciplines was

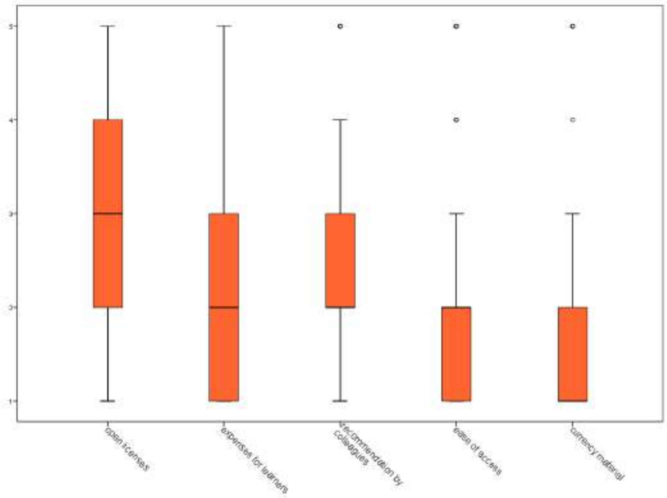

Fig. 2. Boxplots showing criteria for resource choice: "What criteria do you consider when choosing your learning resources?", Likert-scale 1 (very important) to 5 (not important at all).

adapted to general disciplines at German higher education institutions without any sub-classes. The job position classification refers to common positions in Germany: Professor (all with German professor title, includes associate, full and affiliate professors), special education teacher (staff with specific teaching responsibility like teaching literacy skills), academic (staff with research and teaching responsibility), lecturer (with teaching responsibility only), student assistant (supports teaching and research).

We used SPSS (v23) for statistical analysis, and provide descriptive analysis for all variables. We got 360 responses, whereof 210 were completes and 150 incompletes. Results are based on the 210 complete cases. Significance tests (Chi-Square) considering the job position were done with 207 cases, where we left out two student assistants (not representative for group) and one case with an unclear job position. Two researchers analysed and checked open text questions. We show the most relevant results on specific questions in tables and figures below and discuss them in the subsequent section.

6. Limitations of the survey

Using self-selective online sampling and a purposive dissemination of the questionnaire (Creswell, 2013) – that is aiming at open educational resources and open science communities in Germany – the results are not representative for German teaching staff at higher education institutions. Compared to German micro census data (Statistisches Bundesamt, 2016), we have a higher percentage of professors,

Table 1
Participant demographics

	#	n
Age (as of 2019)		$n = 208$
$>$ 24 years	97%	
$>$ 40 years	70%	
$>$ 60 years	13%	
Gender		$n = 210$
Female	94	
Male	116	
Current position		$n = 210$
Professor	63	
Academic	81	
Lecturer	42	
Spec. Edu. Teacher	21	
Student assistant	2	
Unknown	1	
Discipline		$n = 252$
Natural sciences	39	
Arts/Humanities	111	
Economics	51	
Law	4	
Medicine	6	
Technics/Computer Science/Engineering	41	

lower percentage of academic staff (usually over 60%) and slightly higher percentages of special education teachers and lecturers. We have a few more male respondents (55%), where females should have a percentage of 51%. In addition, some disciplines are under-represented (Table 1), whereas the Arts and Humanities discipline is overrepresented. Despite this, we think our explorative study gives critical insights into the status of openness in higher education in Germany, with implications for further research in other countries.

6.1. Results

Table 1 summarizes the demographic data from 210 cases. The majority of participants was about 40 years old. Please note that this field had two invalid entries. Participants had a multiple choice option for their discipline and some felt they belonged to two disciplines, i.e. n is larger than 210 cases. The Art and Humanities group is slightly overrepresented which might be due to the mailing lists we used to promote our survey.

Figure 2 shows the boxplots for the question on criteria considered for resource choice. The boxplots and the means (Table 2) show that all criteria are important for the participants, with means a rated value less than three (1 = very important). Currency of material and ease of use are the most important criteria for selecting resources for teaching, with also the lowest standard deviation. Open licenses are least important, with a high standard deviation. Table 3 shows the figure on open resources

Table 2
Values for the question on relevant criteria for resources choice

Criteria	M	SD
Currency material	1.70	0.929
Ease of access	1.89	1.077
Recommendations	2.49	1.191
Expenses for learners	2.58	1.364
Open educational licenses, e.g. CC-BY	2.73	1.343

use and its creation and sharing. There are no significant differences between the use of open resources and a person's position or discipline, except for economics where fewer people than statistically expected use open resources (χ^2 (1) = 4.42, $p < 0.05$, $N = 210$). There is a difference regarding gender and open resources usage, female respondents use open educational resources more often (χ^2 (1) = 5.66, $p < 0.05$, $N = 210$). 46 out of 94 females use open resources, while only 38 out of 116 males use these resources. Regarding the creation of open resources, there is no significant difference. Here, academics seem to be the most creative, with a number slightly above the statistically expected number and over half of them (21 out of 36 that use open resources) creating open resources.

Survey question: "What criteria do you consider when choosing your learning resources?", Likert-scale 1 (very important) to 5 (not important at all).

Regarding collaborative tools used in courses, we asked the participants to distinguish if they use tools only for the provision of course resources, only for communication and collaboration between lecturers and students, or for both of the prementioned tasks. Participants had the option to state that they do not use any tool. Distinguishing between usage and non-usage, most participants used two collaborative tools (Fig. 3). The tools used most often (Fig. 4) are email and institutional learning platforms, both tools also rank first and second in combination. They are followed by file-sharing and open tools. However, the top two tools are used twice as much as open tools. For example, open tools like open blogs or forums are used by 70 out of 210 participants (30%).

There is a tendency that professors and academics use "traditional academic tools" (such as reference management tools) more often than special education teachers and lecturers. Special education teachers and lecturers tend to use non-academic tools like blogs (over 23% compared to less than 15% for both academics and professors) and editing tools like Google Docs (over 36% compared to 26% for academics). One reason might be that not all lecturers and special education teachers have access to academic tools (e.g., some reference management tools require licenses). Usage numbers for Wikis and open forums are quite similar over all positions and lie between 28–35% (Wikis) and 27–38% (open forums).

The top tools used for course resource provision are file sharing tools and institutional learning platforms that are used more than twice as much (both are marked 47 times, 22%) as other tools Fig. 5). The top tool for communication and collaboration by far is email, mentioned 102 times (49%). Institutional learning platforms (50%)

Table 3
Open educational resources use and creation ($n = 207$)

Current position	Use educational resources	Create and create open educational resources
Professor		
%	30.2	12.7
n	19	8
Academic		
%	44.4	25.9
n	36.0	21
Lecturer		
%	35.7	16.7
n	15.0	7
Spec. Educ. Teacher		
%	57.1	23.8
n	12.0	5
Natural sciences		
%	36.8	15.8
n	14.0	6
Art/humanities		
%	44.5	24.5
n	49.0	27
Economics		
%	27.5	13.7
n	14.0	7
Law		
%	0.00	0.0
n	0	0
Medicine		
%	16.7	0.0
n	1	0
Technics/computer science/engineering		
%	40.0	17.5
n	16.0	7
Total		
%	39.6	19.8
n	82.0	41

and email (37%) are also also tools often used for both, provision of resources and communication and collaboration, whereas open tools (15%) and closed wikis (14%) follow on third and fourth ranks. We found a tendency that lecturers and special education teachers use tools like blogs and Google Docs more often.

The last part of the survey investigated questions around student participation, sharing and assessment, i.e. aspects mentioned with regard to open educational practices and pedagogy (Table 6.1). Although academics are the largest group supporting resource sharing, they do not explicitly require it from their students. On the contrary, there are exactly twice as many professors who do require in-course sharing than those who only offer sharing options. Require in-course sharing from students was the

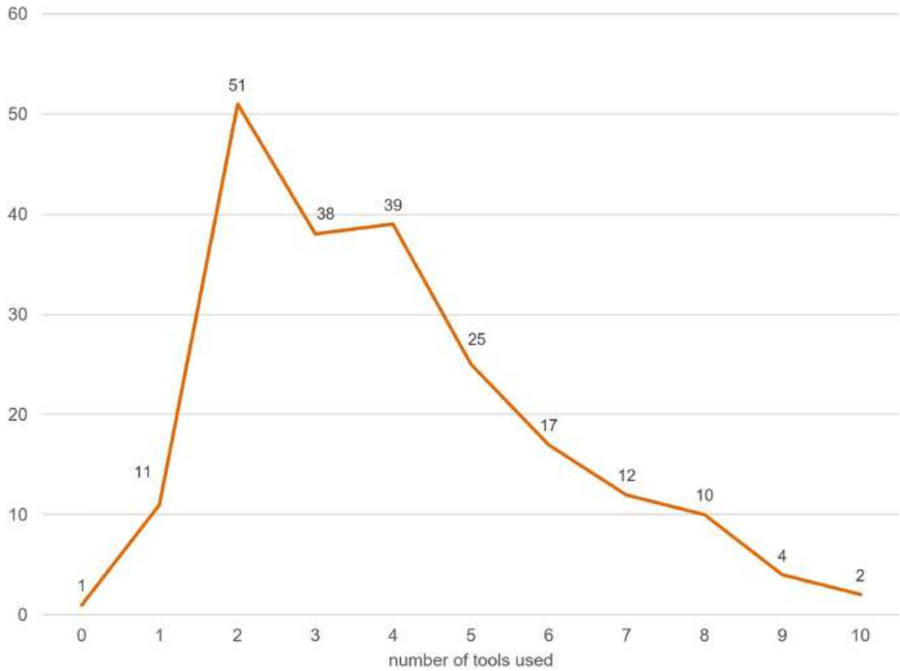

Fig. 3. Number of collaborative tools used per participants.

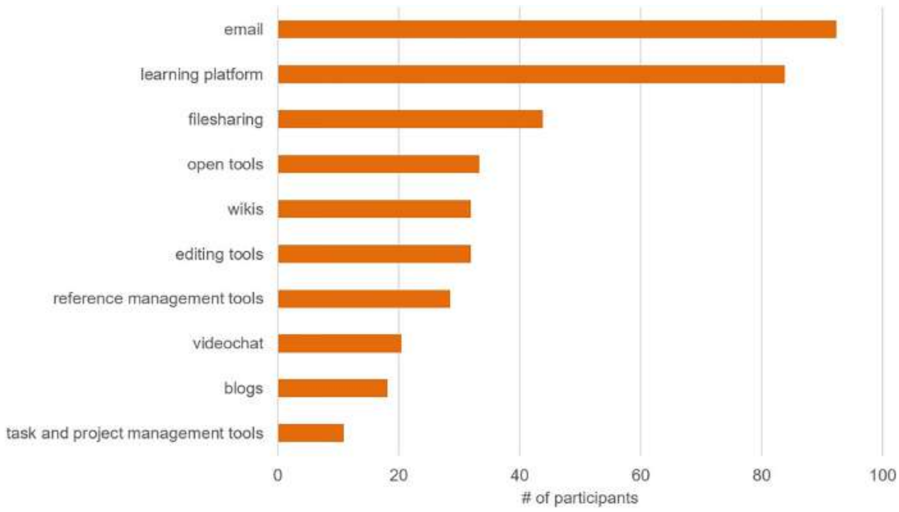

Fig. 4. Tools used.

Table 4
Student work and material sharing and assessment ($n = 207$). Single choice, participants should state on their most commonly situation

Current position	I do not want to see my students sharing their work with others	I offer options for students to share their work, but I do not explicitly require sharing	My students shall share their work with other students in the class	My students shall share their work with other students from my institution	My students shall share their work with other students as well as with the open online community	I request my students to share their work and consider it for my assessment of each student
Professor						
%	17.5	22.2	44.4	7.9	7.9	48.1
n	11	14	28	5	5	25
Academic						
%	8.6	45.7	32.1	2.5	11.1	23.0
n	7	37	26	2	9	17
Lecturer						
%	9.5	31.0	45.2	7.1	7.1	23.7
n	4	13	19	3	3	9
Spec. Educ. Teacher						
%	14.3	28.6	38.1	9.5	9.5	38.9
n	3	6	8	2	2	7
Total						
%	12.1	33.8	39.1	5.8	9.2	31.9
n	25	70	81	12	19	58

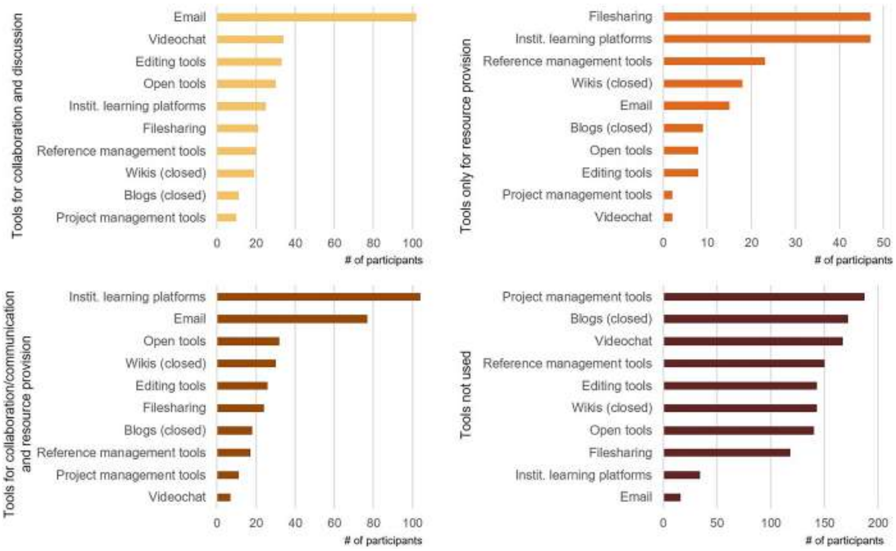

Fig. 5. Tools used distinguishing between purposes.

most popular answer for all job positions except with academics. We asked if participants assess students sharing, that is if students' grading is dependent on sharing materials. Professors, who require sharing in their teaching more often, also assess students' sharing activities (48%). Over one-third of special education teachers assess sharing, within the lecturers and academics group it is less than 25%. In addition, 68% of the participants stated that they offer opportunities for students to co-create and determine course content (Table 5). The behaviour significantly correlates with the use of OER (χ^2 (1) $= 7.07$, $p < 0.01$, $N = 210$), although not with its creation.

Participants that opt for student co-creation said that most of the course content is predetermined with options to consider students' interests (50%) or that the course basics are predetermined, but specific foci are determined together with students (43%). Only 6% of the participants opt for a more radical answer stating that course content derives out of discussions and determinations together with students during a running course. Here, special education teachers and lecturers were more likely to choose the latter version, being 13% and 12% compared to less than 4% for academics and professors.

7. Discussion

In the following, we discuss the highlight-findings, grouped in 1) open educational resources, 2) tools and activities, and draw upon challenges and opportunities for open practices.

Table 5
Student co-creation in courses ($n = 141$). Yes/No answer, 2$^{\mathrm{nd}}$ question (single choice) answered by 141 participants, who allow co-creation

Current position	Yes, students are allowed to co-create course content	My course plan is mostly set, but I leave room for my students' interests	I have a course plan and topics in mind, but determine specific topics and foci together with my students	I really consider my students' interests. Thus, I determine my course plan and topics together with them after the class has started
Professor				
%	58.7	54.1	43.2	2.7
n	37	20	16	1
Academic				
%	67.9	52.7	43.6	3.6
n	55	29	24	2
Lecturer				
%	78.6	45.5	42.4	12.1
n	33	15	14	4
Spec. Educ. Teacher				
%	76.2	43.8	43.8	12.5
n	16	7	7	2
Total				
%	68.1	50.4	43.3	6.4
n	141	71	61	9

8. Open educational resources: Awareness and use

Overall, our findings match the results on open resources use that were reported earlier (Bossu et al., 2013; Boston Consulting Group, 2013b; Seaman & Seaman, 2018). The survey showed that four out of ten respondents (is it 40%) use open resources which is slightly less than found by recent other studies. A recurrent U.S. study shows an increase in the awareness from 34% in 2014–2015 to 46% in 2017–2018 (Seaman & Seaman, 2018). This trend indicates a rising awareness among teaching staff in the US. However, our study shows that 60% of all respondents indicated they did not use OER, which is still a high proportion. Please note that we did not explicitly ask respondents if they use OER or not, but we asked if they were at least aware of them. A survey sent to staff at Australian universities revealed that 60% of the participants were aware of open resources (2013).

Our study shows that there are challenges that might hinder open resources usage: Participants stated that they have not heard of open educational resources (46%, Table 3), and that there is a lack of material available for their discipline that promotes OER (53% compared to 49% in (2017)). Some participants neither see a need nor a benefit to open resources, nor do they assume that they could create open resources on the basis of their teaching material. Others have difficulties in finding resources. In addition, participants commented that they have "no time to go through all the materials". Similar to other study results (2017), 45% of the participants criticize that there is no resource catalogue. Those results show that work needs to be done to facilitate an easy way of searching and finding open resources and systems that consider them with regards to the needs of diverse disciplines.

Half of our respondents who know open resources also produce and share them (Table 3). Those that do not produce them find it both too laborious and time-consuming, or they do not know how to do that. This confirms the reasons for not producing open resources as found by (2013), although this applies to fewer respondents from our sample.

Our answers suggest that the digitality of learning and teaching material, that provides options for easy access and distribution, is considered a more important aspect than openness. This may be an indication that the concept of open resources and the properties belonging to it are not fully understood or not valued equally. As proof for the latter we can look at the drivers behind resource selection. Although 77% of the respondents know the license which determines a resource's options for reuse, the selection of teaching and learning resources is mainly driven by their currency and ease of access as well as by their relevance for the topic taught and their quality (Fig. 2, Table 2). Open licenses, on the other hand, are neglected by the majority of respondents when choosing learning and teaching material. Respondents even stated: "Quality of content is key: whether I have to pay for it or not" and "negligible in as much as students have access".

There is a substantial number of respondents who do not use open resources (60%) because they are either not aware of them or do not know what they mean, although we have not explicitly asked about the latter. These seem to be common problems faced by the OER movement, as demonstrated by other similar studies (Bossu et al., 2013). This finding is remarkable, though, despite major efforts from a range of stakeholders, national and international, to increase awareness and to provide access to open resources and promote activities via large initiatives. This still remains an considerable issue to be addressed, and perhaps one way to address this problem would be to increase capacity building and training of university teaching staff could.

9. Open tools and activities

It seems that there is a tendency that professors and academics prefer established academic tools such as literature reference tools. Special education teachers and lecturers tend to use non-traditional academic tools such as editing pads or open wikis. One reason may be that the latter group do not have proper access to academic tools, for example because of license restrictions. Despite this tendency, email is still the tool most used (Figs 4 and 5).

Results may be influenced by how the survey questions were formulated, though. We asked participants to state the current tool usage and did not ask them to state whether they have ever used those tools, whether they just do not know them, or whether they have particular reasons to not use them. It would be interesting to study whether their choice of tools is influenced by external factors – like institutional regulations, restricted options in designing a course – or if participants did test diverse tools in the past and found their personal favourites as a matter of best practices that also fit the current educational environment best. More research has to be done considering the teaching staff's opinion on and choice of good teaching practices and use of open technologies and pedagogy, specifically with regard to their specific educational contexts.

We were also interested in the ways teaching staff integrates and fosters open practices in education and what serves as incentives. We assumed that teachers do not feel too comfortable with using the technology (2008) and expected a conflict to occur between openness, collaboration, and assessment in class (2012). Our study reveals similar results regarding the use of tools defined as open Web 2.0 tools. Only 33% do use them. However, over half of the respondents require students to share their works using any kind of digital technology (Table 6.1). We asked them, in which form students should share their work. One of ten respondents said they engage students to share work openly on the web.

Brown's (2012) study revealed that some academics have difficulties in finding "an appropriate balance between assessment and student collaboration via Web 2.0" (Brown, 2012, p. 56). Outcomes from our survey reveal not a resistance against open practices in general, but a lack of assertion in practical applications and handling. Reasons for not using open resources and comments like "I miss further training in this field" or "I would appreciate a better search for open resources and open licenses" show that teaching staff needs more support to adapt to open practices.

Comparing the related studies with our survey results, we also see that to overcome challenges of open practices, different levels of openness must be considered and discussed, for example openness within class, openness within an institutional learning platform, and openness within the web that potentially reaches the entire public. This differentiation seems to be reasonable in order to introduce open practices, to respect institutional and social requirements and to increase chances that open practices will be applied. This, however, also shows that, further infrastructures and support are needed to enable full embracement of openness.

Opening up science comes with similar difficulties. Practicality concerns may hinder research to fully adopt open practices. As well do external requirements (like publishing in non-open-access Q1-journals) and concerns of research impact – although open access publication do get more citations (Piwowar et al., 2018). If teaching and learning becomes more open and offers ways for students to access content, to participate and to co-create, this fosters a way towards openness in research, i.e. research that opens its community for students and is able to raise awareness of those critical issues beyond internal borders. Our study shows a relation between the use of OER and supporting student co-creation. Here, positive synergies can be used. Raising OER awareness, specifically via improving search, findability and accessibility with proper infrastructures, can support open educational practices and open science.

In addition, to adopt open practices strong incentives are needed, which confirms the results of Brown's study (2012). One participant stated: "Potential of open educational resources is overestimated. Students are busy and just want to pass the course." Academics are especially keen about sharing the works of students. The main reason for this seems to be that academics want to prepare students for a future academic and professional career that increasingly entails aspects of open science and surely requires knowledge about open practices. However, the statement also reveals some disappointment about the clash of good intentions and their practical implementation. Hence, almost 30% of the teaching staff uses grades to incentivize sharing and along with it open practices among students, like co-creation of course content.

Regarding the latter aspects through an openness lens, we also must distinguish between levels of collaboration regarding diverse study and course forms. To teach courses with a high degree of openness, like high levels of co-creation and communication options, might overstrain early semester students, whereas more experienced students in their Masters can benefit. Survey participants stated that the level of student experiences and skills influence their practices.

10. Challenges and opportunities for openness in higher education

Our survey did not explicitly ask what kind of support or infrastructures teaching staff needs to facilitate open practices. However, the explanations on why participants are reluctant towards open practices revealed fundamental issues in this regard. A majority of participants lack the knowledge to include open practices and are willing to seek for assistance: "I need more help in this area: What is available? How to do it?" This finding confirms earlier recommendations to offer training to teaching staff so that they can master the technology needed in future (2008). Although there are larger service-like projects that collect and share information about OER and open practices and offer practical support, like FOSTER (fosteropenscience.eu) and OERInfo (open-educational-resources.de) to name only two for the European and German region, it seems that educators lack awareness of those offerings. Many services and infrastructures are established by now, or are in the developing phase, and proper communication about those is needed. In contrast, research shows that personality and external factors influence the adoption of open practices in science (Kim & Stanton, 2016; Linek et al., 2017) and education (Bossu & Stagg, 2018) and that we need to find out more about those constraints.

In addition, open practices literacy has to be improved, i.e. literacy on the current state of open resources and open pedagogies (compare Ehlers and Stracke (Ehlers & Stracke, 2012)). We may even assume that as soon as open practices are mediated in the most natural way the learners will take them as a matter of course and will fully embrace them. This is a major point that will help fostering open practices: Taking away personal and practical boundaries for future researchers is essential to make open science a default.

Table 6
Open educational practices to foster open science

Open educational practices	Contribution to open science
	Awareness of and skill development for...
Use and create open educational resources	...open access publishing of research outcomes
Use of open tools for sharing resources	...tools and techniques to share research like data and methods
Options for open communication and collaboration	...open research communication, like open peer review
Options for co-creation	...research community and research method practices

Technical support and easy to use infrastructures are needed to support open practices. Concrete demands were formulated from our survey participants: "Filter for CC licenses and open resources in library systems are needed". Here, one important fact became apparent again: local support and infrastructures such as libraries (Bueno-de-la-Fuente et al., 2012) are the major facilitators and drivers of OER. They can provide the fruitful ground and incentives (such as open practice awards) that teaching staff needs for adopting OER and additional open educational practices.

Based on our understanding of open practices and their implementation in the education environment, we think those practices can foster further openness in science and research (Table 6). Offering students opportunities via open educational practices raises their awareness of future open science goals and teaches them the skills needed to become a researcher that successfully conducts open science in the future.

Our survey built on our understanding of open practice and gives first insights on the status of those practices in Germany. Although we cannot generalize our findings, we showed how a broader view on open educational practices might look like and which implications might be possible. More research has to be done to understand the context and influence of different education environments (like higher education, vocational education) and country-dependent regulations (like open resources policies, copyright).

Although not focus of our study, we would like to make the point that where the interrelation and potentially fruitful coaction between research and education become obvious. Pedagogical concepts of research-oriented learning focus on students as researchers and teaching research skills (Brew, 2013). "Learning through research" aims at letting students participate and engage in a research process. They need the opportunity to formulate research questions and co-design and reflect on research aspects (Reinmann, 2016). Aspects like student engagement and participation discussed within concepts of research-oriented learning are similar to those discussed within open science and education and would easily complement each other (Heck & Heudorfer, 2018). The open education concept emphasizes the importance of students being allowed to actively participate in the scientific community to understand what research is about and to apply this knowledge in their studies. "Indeed, one of the goals of open education is to move learners closer to the centre of a community of practice, specifically through providing opportunities and infrastructure for participation and collaboration" (Blessinger & Bliss, 2016b, p. 14). Brown (2012) emphasizes the high potential to build a bridge between teaching and current research, it allows students to become a member of a "knowledge creating collective" (Brown, 2012, p. 56), where they benefit from and contribute to the research community.

11. Conclusion

We discussed the interrelatedness between open practices in education and science and claimed that open science need to be fostered by educational practices that refer to goals in open science. We conducted an online survey to shed light on the status of those practices in German higher education institutions.

Our results point out that open practices have not yet been fully achieved in higher education. Open resources are not popular, and prevailing email as a digital teaching tool does not contribute to open practices that foster a community awareness and sense of belonging. Respondents undertake activities related to openness like encourage students to share their content and be co-creators of resources, but those activities are not common place. Here, we still see challenges in bringing open practices and existing higher education practices together. However, independently from our aim to relate practices in science and education, we need to investigate what benefits and learning outcomes open practices will have in context of science and education. In addition, answers showed that teaching is very diverse and has different needs depending on the form and discipline of teaching. Further research should investigate as to how far open practices can be integrated in different scenarios and environments and what support educators require.

Regarding our survey results that show the current state of practices in German higher education institutions, further research has to be done to better understand the motivations and attitudes of lecturers (Weller, 2014), specifically those who practice teaching and research and are able to bridge both fields. In addition, we need to investigate benefits of open practices with regard to pedagogical aims as well as aims intended in the open science movement. This again is an argument to investigate further open practices in relation to research and education.

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Learning Open Science by doing Open Science. A reflection of a qualitative research project-based seminar

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Openness in science and education is increasing in importance within the digital knowledge society. So far, less attention has been paid to teaching Open Science in bachelor's degrees or in qualitative methods. Therefore, the aim of this article is to use a seminar example to explore what Open Science practices can be taught in qualitative research and how digital tools can be involved. The seminar focused on the following practices: Open data practices, the practice of using the free and open source tool "Collaborative online Interpretation, the practice of participating, cooperating, collaborating and contributing through participatory technologies and in social (based) networks. To learn Open Science practices, the students were involved in a qualitative research project about "Use of digital technologies for the study and habitus of students". The study shows the practices of Open Data are easy to teach, whereas the use of free and open source tools and participatory technologies for collaboration, participation, cooperation and contribution is more difficult. In addition, a cultural shift would have to take place within German universities to promote Open Science practices in general.

Keywords: Open science, open education, digital practices, habitus, digital technologies

1. Introduction

Openness in science and education is becoming more important in the digital knowledge society. Openness is discussed in a number of different ways: in research, under the heading Open Science (OS) and in teaching under the headings Open Education (OE) and Open Pedagogy. OS is also an umbrella term (Fecher & Friesike, 2014) incorporating various concepts. For more clarity, the EU-funded FOSTER Plus project (Facilitate Open Science Training for European Research) created a taxonomy defining OS. This taxonomy includes the following: *Open Access* means free access to scientific results, *Open Data* comprises the online provision of research data collected in research projects, which is made freely available for re-use. *Open reproducible research* is an OS practice enabling the independent reproducibility of research results. *Open Science Evaluation* includes Open Peer Review as well as Altmetrics or Bibliometrics. *Open Science Tools* refers on the one hand to software that can be accessed online free of charge and on the other hand open to platforms for workflow and repositories (Pontika et al., 2015). The aspects listed in the taxonomy cover the entire research process from data generation to the evaluation of the research results by the scientific community.

Along with OS, there is also an OE Movement. As Weller (2018) explains, OE is strongly influenced by the Open Education Resources (OER) movement and the 5Rs. The 5Rs are Reuse, Revise, Remix, Redistribute and Retain (Weller, 2018). Similar to OS, OE is a broad concept that can be interpreted from a narrow use and re-use of OER to a much broader understanding as OE practices (Bellinger & Mayrberger, 2019). OE practices include the creation, use, and reuse of open educational resources (OER) as well as open pedagogies and open sharing of teaching practices (Cronin, 2017). As Weller (2018, p. 57) further explains, some principles are central to OE: "freedom to reuse; open access; free cost; easy use; digital, networked content; social, community-based approaches; ethical arguments for openness; and openness as an efficient model". In accordance with Open Pedagogy, also central are: "participatory technologies and social networks for interaction, peer-learning, knowledge creation, and empowerment of learners" (Cronin, 2017, p. 4).

In an attempt to combine OS practices of research with practices and principles of the OE practices of teaching in higher education, I developed a project-based seminar concept and generated an OS tool (KolloIn: Collaborative online interpretation). I tested both in a university course in sociology in Germany. The seminar was integrated into the author's qualitative research project "Use of digital technologies for the study and habitus of students", using the habitus-hermeneutic (Bremer & Teiwes-Kügler, 2014). A project-based learning setting was used. This setting was selected because including students in research projects leads to a deeper understanding of the methods and the research process (Healey, 2005). This goes hand in hand with an understanding of learning as a process, one that takes time and can be accompanied by a change in practices. Learning is also "not something done to students, but rather something students themselves do" (Ambrose et al., 2010, p. 3).

Open digital research practices are not yet widespread, particularly in qualitative research (Steinhardt, 2018). Therefore, the aim of this article is to use a seminar example to explore which OS practices can be taught in qualitative research and how digital tools can be involved.

To answer these questions, three levels are considered. The first consideration is the structure of the seminar and the Open Source tool KolloIn. Secondly, it will be discussed what offers are needed to teach OS practices and how students accept OS/OE practices as well as which insights were gained into basic principles and the practical handling of OS. Thirdly, the level of the research project will be considered. This level reflects which research-related theoretical and empirical findings can be drawn on the habitus and use of digital technologies.

The following chapter distils OS practices from the literature that is already used in teaching and combines them with OE practices to form characteristics of OS/OE. I then go on to describe the research project of which the project-based seminar was part. The next section focuses on the seminar concept details. In the fifth chapter, I use the characteristics of OS/OE developed in chapter two to describe the taught practices. Finally, I discuss the experiences of the seminar and give some ideas for further development of teaching OS practices in a digital world.

2. Teaching Open Science – State of the art

As Steinhardt (2019) illustrates, teaching OS and involving students in OS projects is not an extensively discussed topic. However, one exception is the involvement of students in replication studies (Chopik et al., 2018; Janz, 2016). Replication of research and the re-use of data in connection with the replication crisis is discussed. The term replication crisis refers to the difficulties involved in reproducing results from scientific studies (Randall & Welser, 2018). The authors (Frank & Saxe, 2012; Grahe et al., 2012; Hawkins et al., 2018) argue replications are time-consuming and expensive, and "normal" researchers are often unwilling to do this task. One response to these challenges is for students to conduct replication studies with open data (Frank & Saxe, 2012; Hawkins et al., 2018; Toelch & Ostwald, 2018). Thereby, students could learn not only the scientific process, but also the importance of methodological standards. In addition, students could learn the value of openness (Frank & Saxe, 2012). Frank and Saxe (2012) highlight the importance of collaboration between instructors and students both in identifying interesting experiments and in cooperating on the identified replication studies. They also mention four benefits of replication seminars: First, student motivation is higher than in normal seminars because of the possibility to contribute research results to the scientific community. Secondly, this possibility leads students to be more attentive to the process, thus methods become more concrete. Thirdly, as students need the literature for their own experiments and calculations, they tend to be more thorough in their reading. Fourthly, students experience first-hand the frustrations of poor documentation about experiments and calculations and, as a result, reflect better practices (Frank & Saxe, 2012).

Replication studies are often dependent on access to data. Therefore, one of the central aspects of the OS movement is open data, which includes the documentation and archiving of data. These aspects are taught in data management courses (Piorun et al., 2012; Whitmire, 2015). Data management includes "to be aware of and adhere to their principal investigator's plan for the effective management, storage, and sharing of research data" (Adamick et al., 2012, p. 180). Developers of the curriculum and associated modules are mostly librarians who perceive teaching data management as a new task for libraries (Schmidt & Holles, 2018). In order to reuse data, students need digital literacy skills that must be trained in the classroom (Cook et al., 2018).

Open Source Software (OSS) is a major topic in computer sciences (Braught et al., 2018; Faber, 2002; Nandigam et al., 2008; O'Hara & Kay, 2003) and in geospatial science education (Mitasova et al., 2012; Osaci-Costache et al., 2017; Petras et al., 2015). Petras et al. (2015, p. 943) point out, integration of free and open source software in geospatial science education is necessary "to encourage a culture of openness and, thus, enable greater reproducibility in research and development applications." For computer sciences, O'Hara and Kay recognize that: "OSS has the potential to expand group work beyond the classroom to include much larger projects and more distributed teams. OSS can also be used to introduce our students to the larger computer science community and to the practice of peer-review. Finally, OSS can often provide us with free or lower-cost technology in the classroom, permitting us to use technology that we might otherwise be unable to afford." (O'Hara & Kay, 2003, p. 1) The use of free and open sources is also widespread in business. This gives computer science teachers the opportunity to work with realistic software systems and real code cooperating with companies (Buffardi, 2015; Carrington & Kim, 2003; Sowe & Stamelos, 2007). "Using open source software also has the beneficial effect of ensuring that students are aware of the open source software movement, and opens up opportunities to discuss topics such as software piracy and ethics" (Carrington & Kim, 2003, SIC 9).

Collaboration and cooperation are important topics in OS and OE. Wikis are used in teaching to enable and promote cooperation and collaboration between students (Bruns & Humphreys, 2005). Particular attention is paid to "collaborative and responsible learning" (Jaksch et al., 2008, p. 77) as well as cooperative learning (Schaffert & Ebner, 2010) and the generation of open knowledge through wikis (Ebner et al., 2008).

In summary, there are certain elements of OE that are implemented in the teaching of OS:

- Open data practices for reuse, replication, revise and archiving. Archiving also includes practices of data management.
- The practice of using free and open source software and tools, including the discussion about usability and ethics.
- The practice of participating, cooperating, collaborating and contributing through participatory technologies and in social (based) networks especially wikis but also tools for coding and seminar communication.
- Knowledge creation and empowerment of leaners through project- or research-based seminars according to OS (including use and reuse of Open Access papers).

With respect to the second aspect of the seminar, the use of qualitative data, only a few studies could be found that address qualitative research by focusing on the sharing and re-using of qualitative data. While these studies are not project-based, they nevertheless show teachers how to use open qualitative data (Bishop, 2012; Corti & Bishop, 2005; Kretzer, 2013). However, little is known about how a qualitative project-based OS seminar could look like and how OE practices could be integrated. Therefore, I will present the seminar structure using the list above as an analytical framework to analyse the seminar. Before discussing the seminar, I briefly describe the project the seminar was part of.

3. The research project “Use of digital technologies for the study and habitus of students”

The project-based seminar was part of the author’s research project “Use of digital technologies for the study and habitus of students”. The findings from the project on the use of digital technologies by students are also relevant to the seminar. They explain why the change of practices is difficult and time-consuming. Germany is a latecomer with regard to the use of digital technologies in teaching at universities. A study by Persike and Friedrich (2016) assumes that students use conventional media more often because teachers introduce conventional media in their courses. Furthermore, teachers do not provide guidance on how to independently search and find other digital learning materials. However, these instructions are necessary as, despite what is commonly believed, digital natives or a net generation do not exist (Kennedy et al. 2008; Rowlands et al. 2008; Kirkwood & Price, 2005). Accordingly, students do not automatically have the skills necessary to deal competently and critically with digital technologies and Web 2.0. Rather, they show divergent practices of acquiring media competence (Schulmeister, 2009). This diverse digital literacy could lead to a second digital divide (van Deursen & van Dijk, 2019).

The different approaches to digital technologies may be influenced by the habitus and thus lead to orientations acquired in local social contexts and class positions (Ignatow & Robinson, 2017; Robinson, 2009; Robinson et al., 2015). According to Bourdieu’s theory, the habitus represents the incorporated patterns of action, thought and perception inherited in one’s own social context (Bourdieu, 1977, 1984). These patterns are based on social, cultural, symbolic and economic capital, whereby the capital is distributed differently among the social classes. Social capital describes the social relationships that someone can fall back on, while symbolic capital describes prestige and recognition in society. Cultural capital is associated, for example, with education and academic titles. Economic capital refers to the material resources available to a social subject. Due to different access to these types of capital, a class habitus is formed that manifests in the preferences and above all in the practices of people. Thus, practices are the “link between social structures and the personal way of life” (Zillien & Marr, 2013). Therefore, how students use digital technologies may be due to their habitus, and may, as a result, reproduce existing social inequalities in higher education, or even produce new inequalities because of the second digital divide.

Based on these findings, I assumed the participants had little experience with Web 2.0 applications at the university so far. Additionally, these findings were the theoretical starting point for the students in my seminar to determine the use of digital technologies and the habitus. Therefore, the students conducted narrative interviews (Nohl, 2010) using the habitus-hermeneutics method (Bremer & Teiwes-Kügler, 2014; Lange-Vester, 2012; Lange-Vester & Teiwes-Kügler, 2013) to reconstruct the habitus of the interviewed students and discover if there is a connection between the habitus and the practice of using digital technologies for studying. The following sections outline the method, the interviews, and the structure of the seminar.

4. The seminar plan and participation

The seminar entitled “Finding the connection between digital media and habitus with qualitative methods” (Dem Zusammenhang von digitalen Medien und Habitus qualitativ auf der Spur), was part of a BA study programme in sociology at the University of Kassel, Germany. The seminar was open to sociology students as well as for teacher training students.[1] It was an optional seminar. Thirteen students participated in the course – nine sociology students and four teacher training students. Nine students were female, four were male.

In the introductory session, I gave an overview of the project-based learning setting and presented the research project of which the seminar was part of. I also inquired about the students’ knowledge of digital technology user practices, the habitus concept and whether they had ever collected data themselves. It transpired that only one student had heard of the concept of habitus and no one had ever collected any data. Three of the four teacher training students had prior experience with digital tools for school lessons. Nevertheless, none of the students had ever been scientifically involved with digital technology or digital usage practices.

Due to the little theoretical knowledge of the students, the first part of the seminar lessons was spent on teaching the basics of the concept of habitus and students’ use of digital technologies. I tried to use open access publications such as the meta study on students’ use of media (Steffens et al., 2018). In the case of the habitus theory, however, it seems that publications are not openly available online. Therefore, I uploaded these publications to the Moodle system used at the University of Kassel so students could gain online access.

The second part of the seminar focused on the interviews the students had to conduct. Based on the studies on student’s use of digital technologies, the seminar group jointly developed questions for the interviews. Additionally, the students received a comprehensive introduction in conducting narrative interviews. Finally, only five students conducted an interview in order to obtain an examination. The other students, who only wanted to receive proof of attendance, took part in the course without conducting an interview.

The last part of the seminar included the interpretation of the interviews. The interpretation took place in the seminar with both an on-site group and online group. At the end of the seminar, both students and teacher gave feedback about the seminar, the online tool, and the interpretation sessions. Also, I offered an interpretation session during the semester break, to discuss questions and further interpretations for those students who wrote a seminar thesis.

[1] In the federal state of Hesse, it is compulsory for students of teacher training to attend seminars in the fields of political science, history or sociology. The students can choose the seminar by their interests.

5. Learning Open Science by doing Open Science

Here I describe the OS practices I taught to the students. To analyse and reflect on the seminar concept I will use the list of OS aspects integrated into OE developed from the literature in chapter two.

5.1. The practices of open data

To describe the practice of open data in the seminar presented here, it is first necessary to describe the process of conducting the interviews. As mentioned, the students conducted narrative interviews to reconstruct the practices of using digital technologies and the habitus of students. Schütze (1977) developed the narrative interviewing method in the 1970s. This method allows the reconstruction of the biography and the underlined experiences the interviewed person has. In a narrative interview, the interview persons put the made experiences into context so that the interviewer can understand them. Through these connections, the everyday practices that underlie these experiences can be reconstructed. Narrative interviews are conducted openly, i.e., no fixed guideline is used. This allows the interviewees to set their own priorities in the narrative.

As mentioned, the students had no experiences with empirical qualitative research. They did not know how to conduct an interview, nor how to identify topics they should address in the interview. To prepare the students for the interview situation and to empower them to identify topics that might be relevant for the project topic, I selected literature that points to possible connections between habitus and digital technologies. From this literature, the students were expected to identify topics themselves. However, a significant level of guidance was needed to establish this knowledge transfer. The topics we identified together were:

- Social background of the family and how digital technologies were used in the family.
- School time in general and if and how digital technologies were part of school.
- The peer group at school and the peer group in the university and how they use digital technologies.
- How the interviewees use digital technologies for study purposes.

In preparation for narrative interviews, we jointly developed an open introductory question in the seminar. The following is an example of how a student asked the prepared question:

> "I: Yes uhh now that we have clarified the formalities, I would like to start with the interview. We had already discussed that it is about the use of digital technologies in your biography and I would now ask you to tell me your biography and how digital media appear in it. Uhhm, it's important for me to say again that you can take a long time for this. I won't interrupt you now and will take notes for any questions I may ask and you can take as much time as you want." (Interview of a student, translation by the author)

As the students were unfamiliar with conducting interviews, they were trained by using role-plays. A central part of the role-plays, was the clarifying of formalities. Since, in the spirit of OS, the aim was to re-use the interviews and to interpret them online, the interviewees first had to agree to this handling of their data and the students were informed of relevant data protection regulations. The General Data Protection Regulation (GDPR) has been in force in Germany and internationally, demanding far-reaching protection of personal data. In order not to violate the GDPR, a comprehensive declaration of consent was provided, which the students used for their interviews. Furthermore, the interviewees were informed in advance of the intended further utilization of the interview material, and they could choose to give their consent to the following:

- Audio recording of the interview.
- Anonymous transcription.
- Use of the anonymous transcript for online interpretation.
- Permission to post the anonymous transcript to a repository for re-use.

Potential interviewees could also receive additional information on the research project provided by my blog posts (https://sozmethode.hypotheses.org/278). Consciously, this should lessen the otherwise prevailing information hierarchy between interviewee and interviewer. Five students conducted an interview. They were free to choose their interview partners. All interviewees agreed that we could interpreted the interviews online and archive for re-use.

After completing the interviews, the students transcribed them by applying the "minimal-transcription" principles of the GAT2 guidelines (GAT = Gesprächsanalytisches Transkriptionssystem – Conversation Analytic transcription system) (Selting et al., 2009). In this form of transcription, the interviews are transcribed literally, i.e. there is no "smoothing" of the text, but intonations, omissions, dialects, etc. are adopted instead (https://sozmethode.hypotheses.org/339). A literal transcription, as directed by GAT, is intended to produce the most authentic picture possible of what has been said thus allowing hermeneutical interpretation.

In the seminar, the students received instructions on how to make the interviews anonymous to make them archival. Identifying all parts of the interview that allow identification of the interviewee is important, such as place of study, place of birth and names and to replace them with placeholders. I chose the "Research Data Centre for Higher Education Research and Science Studies (RDC-DZHW)" in Hannover, Germany (https://fdz.dzhw.eu/en/index_html) as a repository and discussed the decision with the students. The RDC-DZHW is specialized in data in higher education research (in Germany) and thus enables a high visibility of the data. The RDC-DZHW checked the anonymous interviews before archiving and making the data accessible. In addition, the data have received a Digital Object Identifier (DOI) making them easy to find.

The aim of employing open data practices was to teach students how to conduct an interview, which data protection guidelines exist for conducting and re-using interviews, how to transcribe and anonymise interviews so that they can be made accessible for re-use, and how the data management process works.

5.2. The practice of using free and open source software and tools

To interpret the transcribed interviews we used the habitus-hermeneutics method (Bremer & Teiwes-Kügler, 2013, 2014; Lange-Vester & Teiwes-Kügler, 2013; Teiwes-Kügler & Lange-Vester, 2018). This method aims at reconstructing the habitus and the associated practices of individuals through rule-based interpretation. The applied procedure comprises four steps: 1) the creation of an analytical protocol, 2) the conducting of a sequence analysis, 3) the analysis of the habitus based on elementary categories and 4) the formation of the habitus syndrome. Step 2 is particularly important for the analysis, as this is where the opening of the material and the interpretation take place.

Part of the seminar was to enable this step of interpretation through a free and open source tool. However, prior to the seminar such a tool did not exist for habitus hermeneutics. For this reason, we developed the online tool KolloIn (collaborative online Interpretation).[2] For the development of KolloIn we used the open source Semantik DataWiki extension Objective Hermeneutic Interpreter (OHI) (Veja et al., 2017), developed for objective hermeneutics (Schindler et al., 2017). OHI offers more functions than needed for the habitus hermeneutics method we were seeking. Therefore, we reduced the OHI functions for the adoption of the tool KolloIn. KolloIn has two main functions – the possibility to interpret a sequence and generate ad hoc hypotheses (Lesarten), and the option to comment on given interpretations. The second step, the commenting, was only possible when an interpretation had already been given. The following gives an overview of the new tool, providing a more detailed picture of the structure and the steps of KolloIn.

The KolloIn homepage (sozmethode.de) provides information on:

- What hermeneutic methods are and how sequence analysis work.
- How the process of collaborative online interpretation work.
- An overview of all sequences interpreted so far.
- The research project "Use of Digital Media for Studying and Student Habitus".
- How to reuse the software.

The first line of the starting page contains a direct link to the current sequence that is to be interpreted. This link leads to the interpretation page, where users find the title of the sequence, the sequence itself, general instructions, and an overview of the transcription rules. Users are asked to read carefully the sequence line by line. The sequence analysis begins with reading the 'unit of meaning' (Schneijderberg & Steinhardt, 2019). A unit of meaning may be a part of a sentence, a sentence or several sentences. The sequence analysis aims to obtain as many interpretations as possible. All thoughts are welcome, which make the expressions within the sequence

[2] I would like to thank Vincent Mahnke, for technical support and further development of the OHI tool, and Chris Buchheim, who set up and further developed KolloIn for me during an internship.

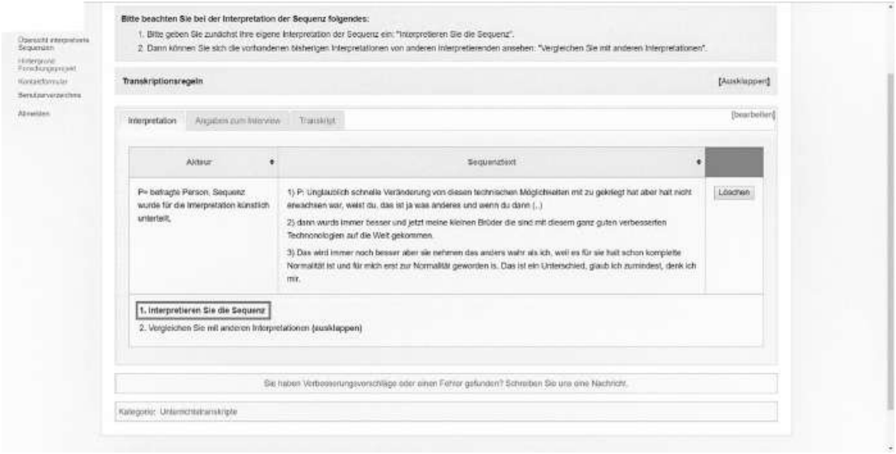

Fig. 1. Starting page of the interpretation process at KolloIn. Source: www.sozmethode.de.

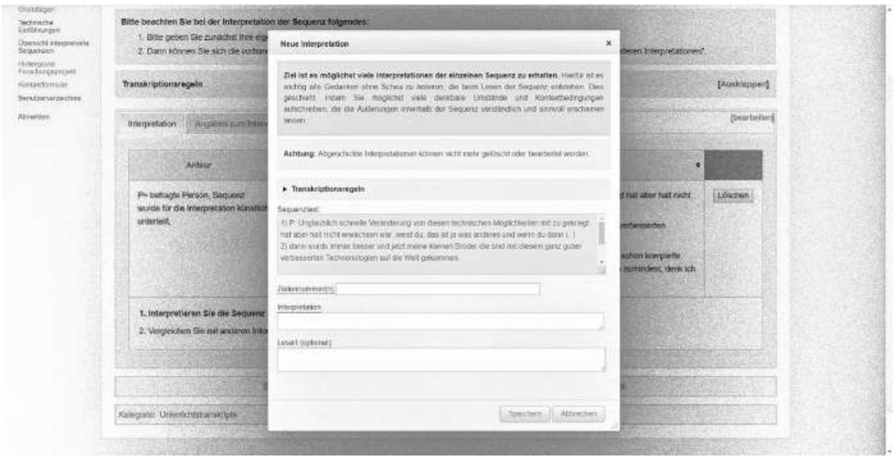

Fig. 2. Entering Interpretation at KolloIn. Source: www.sozmethode.de.

understandable and meaningful (Bremer & Teiwes-Kügler, 2013). The different interpretations of the sequences serve as "traces", that have to be checked, supplemented, and partly corrected in the course of further evaluation. However, more important than conclusive answers in the first interpretation are questions and hints that indicate a direction and can be followed in the further analysis (Bremer & Teiwes-Kügler, 2013, p. 208). A click on the link "Interpretation of the sequence" starts the actual interpretation (Fig. 1).

A click on the link "Interpretation of the Sequence" (Interpretieren Sie die Sequenz) opens the interpretation interface (Fig. 2). Here, again, the user finds the sequence text

Fig. 3. Compare with other interpretations at KolloIn. Source: www.sozmethode.de.

with numbered lines, and an overview of the transcription rules, which if necessary, can be unfolded by clicking on them. Below the sequence text, is a text box "Line number(s)". The lines to which the interpretation refers must be inserted here. A second text box is for the interpretation of the sequence. Below the text box for the interpretation, there is another text box in which ad-hoc hypotheses can be inserted. The interpretation is completed by saving. However, the user can carry out further interpretations at any time by opening up the interpretation interface again. After saving the interpretation, the user can no longer change the interpretation. But the user can comment on the given interpretation. This restriction is important so that the original interpretation remains when the other interpretations have been read.

After having saved the first interpretation, users can compare their own interpretation(s) with others. This operation can be started by clicking on the link "Compare with other interpretations" to be found right below the sequence (Fig. 3).

The page "Compare with other interpretations" offers the possibility to comment on interpretations of others or to add a comment to one's own interpretation. For this purpose, users must press the "Discussion" button next to the interpretation they wish to comment upon. Then, a further text box opens, into which one can type the comment. This offers social media inspired communication and establishes a direct dialogue between users (Schmidt & Taddicken, 2017). Therefore, all comments are immediately published without being first checked by a moderator.

The students had the choice to interpret online or in the seminar. Only five of thirteen students chose to use the online tool. For their choice of online interpretation, the students stated temporal and spatial independence and interest in a new digital tool. The other students preferred to interpret in-class because of uncertainty on how to deal with the digital tool and the openness of interpretations on the internet (even if the interpretations are anonymised) and the certainty of being able to make fewer mistakes in the seminar. These statements show that digital tools in teaching, especially when the results are put online, can lead to barriers. In this context, further options for lowering these mental barriers would have to be considered.

The evaluative discussion with the five students showed that using KolloIn was simple. This simplicity of use was due to the Wiki-Basis, with which all students were already familiar. The descriptions and instructions were also easy to understand.

However, despite the easy to understand instructions, the students still reported difficulties in interpreting the sequences. The difficulties were caused by the uncertainty as to which interpretation was correct and by the fear of giving wrong interpretations. Measures were taken to help students to understand that all interpretations were possible and meaningful in the activity.

Unfortunately, the interaction between the students was low, i.e. they did not use the comment function. When asked why, the students answered that they found it difficult to comment on the interpretations of the others, because they did not know which interpretation was correct. This feedback shows how insecure students are about their own interpretations and how important open tools could be for learning hermeneutics.

Overall, the online interpretations of the students demonstrated an intensive examination of the sequences and a wide range of readings, some of which were wider than those of the in class interpretations. Accordingly, it seems essential to continue working on the possibility of digital online interpretations to fully exploit their potential.

In summary, I did not succeed in creating a comprehensive commitment for the project. Although the students fulfilled the course requirements, voluntary collaboration did not happen. In retrospect, it would have been wise to declare the commenting of the interpretations of others as mandatory.

5.3. The practices of participation, cooperation, collaboration and contribution through participatory technologies and in social (based) networks

Due to the lack of commitment, it was not possible to establish cooperation, collaboration and participation in the seminar via participatory technologies. The students interpreted the text passages via the tool KolloIn (as requested by me), but commenting on the interpretation by others did not happen. I was unable to motivate the students to use social media. At the beginning of the seminar, I tried using Twitter and the interactive functions of Moodle as a communication tool. Despite Moodle being the University of Kassel's well-established organisation and communication tool, the students did not take up this offer and I was unable to convince the students of the benefits of using such communication tools. To establish this form of communication in the seminar, it would have been necessary to demand communication via Twitter as a performance requirement. Furthermore, the proportion of students in Germany who use Twitter is very low, meaning students would need to learn a new tool. However, this was not the aim of the seminar, which focused primarily on research practices.

6. Teaching Open Science practices – A reflection

The aim of the presented seminar was to consider which OS practices can be taught. Within a seminar, practices cannot be learned and existing practices cannot be changed; a longer time period is needed to establish or change practices (Bourdieu, 1977). However, by implementing the seminar as a project-based seminar, I hoped the basic principles of OS would reach the students and they could create knowledge and empower themselves as learners. As the above explanations show, a mixed conclusion can be drawn.

First, the students conducted, transcribed and anonymised the interviews in the sense of re-use and perceived the idea of creating open data from the material as positive. Based on conversations and observations of the students, I assume they have understood the basic principles of the practice of open data. Through their own research, students learned about data protection regulation (GDPR) and its consequences for conducting interviews. The students also learned which regulations must be fulfilled for re-use for the conducted interviews. Through their own research, the students built up competences for their own future research. Whether they will apply the open data practice in the future (for example when writing their thesis) would have to be evaluated. I can only confirm this in one case.

Second, my assumption that students are more motivated in a project-based seminar than in a normal seminar could not be confirmed (cf. for the higher motivation Frank & Saxe, 2012). I observed how the students only worked the minimum amount (which was no more than in other seminars) and were unwilling to do any additional work. I tried to make the project results publicly accessible in other ways, e.g., through a joint blog post, or by publishing excellent term papers, but this was rejected by the students due to the additional work involved. My use of the seminar results for presentations and the naming of the students as project participants was perceived as positive by the students. They welcomed this form of appreciation.

Third, there was a mixed response to the use of KolloIn. On the one hand, only five of the thirteen students were willing to use the digital tool. The reasons they stated were temporal and spatial independence and interest in a new digital tool. At the same time, there was also the fear of doing something wrong and not giving correct interpretations. This fear first had to be removed thus enabling the students to work productively with the tool. Nevertheless, the tool, which is at time of writing unique, worked. This means that it can also be used in other contexts (read more about how it can be rebuilt at www.sozmethode.de). The students positively evaluated KolloIn: it was easy to use because it is a wiki and therefore the design and the application are familiar. But it is unclear whether the students learned about the underlying practice of using it as a free and open source software and what it meant e.g., with regard to ethical and economic contexts.

Fourth, students use digital technologies in their private lives, but the application of digital technologies for their studies is not common practice. This is in line with the research results from chapter three. How digital technologies can be used for learning is not taught comprehensively in schools or universities in Germany. Students do not learn the possibilities of Web 2.0 such as digital communication, collaboration and cooperation. This was also demonstrated in the seminar presented here. Although familiar with this knowledge, I was not didactically prepared to teach these practices to students.

Overall, the reflection of the seminar shows, that since the application of open practices such as digital cooperation, collaboration or participation was not mandatory, these practices were not used. The students contributed to the seminar only what was required. This is unsurprising, as digital practices and the empowerment of learners are not part of the academic habitus in sociology. In German sociology courses, digital offers are limited and the learning of digital practices even less widespread. Study programs in sociology are also characterised by small-scale memorisation or homework that focuses on a minor part of the subject. This means that a project-based seminar is often not a previously experienced practice and therefore uncharted territory. The benefit of extra work is therefore difficult to communicate, particularly considering the large student workload (through part-time work and study requirements). The idea that the students could be a part of knowledge production by doing science is difficult to convey as teachers typically see students as learners who cannot contribute to knowledge production, but rather, are only consumers of knowledge. Most students have adopted this view and have correspondingly a consuming attitude. This attitude is supported or determined by the curricula of the study programmes that in Germany are still predominantly teacher-centred and have not (yet) completed the shift from teaching to learning. The attempt to empower learners could therefore only be implemented to a limited extent. In Germany, the shift from teaching to learning, initiated by the Bologna Process, has not yet taken place, therefore, it is difficult to teach OE practices and OS practices. Open practices aim to change the practices and to develop an open culture of interaction, collaboration and cooperation. These open practices are a retreat from (pre-)lived academic practices. In order to live and teach open practices, however, the conditions at German universities would have to change and a cultural change would have to take place. Because OS practices are not conceivable without digital skills. However, digital literary is not yet a lived practice in Germany, which is why teachers must first address these skills before OS practices can be taught more comprehensively.

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TITLE	SOURCE
Built to last! Embedding open science principles and practice into European universities	Insights: the UKSG Journal (Article from : Scopus)

Built to last! Embedding open science principles and practice into European universities

The purpose of this article is to examine the cultural change needed by universities, as identified by LERU in its report *Open Science and its role in universities: a roadmap for cultural change*.[1] It begins by illustrating the nature of that cultural change. Linked to that transformation is a necessary management change to the way in which organizations perform research. Competition is not the only, or necessarily the best, way to conduct this transformation. Open science brings to the fore the values of collaboration and sharing. Building on a number of Focus on Open Science Workshops held over five years across Europe, the article identifies best practice in changing current research practices, which will then contribute to the culture change necessary to deliver open science. Four case studies, delivered at Focus on Open Science Workshops or other conferences in Europe, illustrate the advances that are being made: the findings of a Workshop on Collaboration and Competition at the OAI 11 meeting in Geneva in June 2019; alternative publishing platforms, exemplified by UCL Press; open data, FAIR data and reproducibility; and a Citizen Science Workshop held at the LIBER Conference in Dublin in June 2019.

Keywords
Open science; change management; open access publishing; research data management; citizen science; research metrics

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> 'Stakeholders should be open to open science, preparing for the future, not clinging to the past.'[2]

Introduction

Open science as cultural change

Open science, that is open research and open scholarship in all disciplines, is a different way of pursuing scholarship. Today, science is carried out in a highly competitive framework. Researchers and organizations compete to promote their scientific assumptions, to win funds, to be the first to discover something or find solutions, and/or to get the best publication space to communicate their success and make their conclusions shine. In this landscape, researchers compete to publish more, compete for attention, and/or compete to win comparative assessments. There is an important observation we should make here: competition is about winning a race where the rules are set by others. Success is measured by someone else's definition of it. Competition is one important element of human progress, but it is not the only one and it usually works better when it is related to other elements, like collaboration.

The authors of this article started to organize a series of events on open science throughout Europe in 2015. The series is called Focus on Open Science,[3] with a mission to promote the concept of, values for and best practices in open science to European communities. Each of these events (called chapters) is organized in close collaboration with a local academic institution, in this way determining each year the topics that are most suitable to be discussed within their own open science landscape, but having in mind the overall recommendations on open science from the European Commission (EC). The series started with one chapter in Ljubljana and the team went on to deliver 11 events in 2019.[4] We reached a number of conclusions during these events and many of them have helped us to orient this opinion piece.

Open science is a different way of conducting research in which collaboration stands right next to competition. This novel route is able to unlock further resources as well as create a more stable, distributed, powerful and sustainable infrastructure that is more efficient than it otherwise might have been. Yes, we do also suggest that funders should look again at the type of research they fund, possibly less oriented to project-based investments. Research investments should match ideas and not the opposite. Great ideas are currently shaped to fit calls for projects and are sacrificed if the competition barometer does not predict success.

'Research investments should match ideas and not the opposite'

In scholarly communication, in particular, which has been transformed from avenues of communication into a network of publication with metrics and analytics, we can see important areas left undeveloped. The results of research are more likely to be published if they are positive. Instead of growing a culture for disseminating the (ultimately important) results of research activity that was conducted rigorously, under a solid methodology which produced important data sets, we have built a system that is doing so *only* if the results are positive, a system that is pushing for certain areas of exploration that are more likely to win the metrics competition. Editors should not make a decision for publication based on results alone. They should do so based on the rigour of the research process and how the results contribute with all their elements to the field of study: from data sets to algorithms and to conclusions.

We would like to highlight what we consider to be the most fundamental difference between locked science (closed science, where data sets are locked in private archives) and open science. Today, locked science is performed within a highly competitive framework, as described above. Competitive research is tracked numerically; researchers keep making comparisons between colleagues and wanting to win.

Competition is built around the verb 'to have' and increases the sense of ownership. Collaboration is built around the verb 'to be' and, amongst other things, it opens up opportunities for new ways of performance. Combining the principles of competition and collaboration, we can obtain the right level of ownership in research (from knowledge to infrastructure) and the right model for collaborative performance that will ensure recognition and sustainability.

Managing the open science transition

There are many challenges in moving to an open science environment, including copyright, costs, data privacy and so on. However, having met with many relevant players in a diverse range of European research communities, we have noticed that the institutions leading in open science all share the same opinion: the most difficult change needed seems to be cultural change.

'change management needs to accompany and support any move to open science'

As the LERU advice paper on open science, launched in May 2018, strongly suggests, cultures do not change overnight.[5] A programme of change management needs to accompany and support any move to open science. Universities need to decide which mix of policies, measures and engagements best supports their missions and implementation strategies. Since these vary across Europe, it is impossible to have identical goals across all universities.

European universities, and to an extent most research organizations, admit that one-size-fits-all solutions are in most cases inappropriate and unlikely to be successful, but there will be areas where large groups can work together on shared goals. Such a commitment is enshrined in the LERU advice paper on open science:

> 'Scholarship is a complex system. Open Science is even more complex The transition to Open Science affects all stakeholders – universities, researchers, teachers, students, funders, publishers, policy makers and support organizations.

Bringing that change at research organizations requires:

1. leadership, vision, strategy and adequate resources for implementation,
2. a mix of targeted measures to achieve cultural change,
3. transparency, accountability and monitoring,
4. trust and confidence in a shared vision.'[6]

The Focus on Open Science Workshops recommend management solutions tailored according to the individual requirements of each institution. What is needed for that?

- Team development: select the right team for the change to transition to open science. Develop sets of skills for your team, both soft skills (management) and hard skills (Open science). Training programmes are a key element, both for staff and for researchers. Consider continuous training programmes for researchers, to include newcomers.
- An irreversible change can only be driven by solid and good leadership, outstanding teams with great skills, disciplined thoughts and actions and shared practice.
- Build tools for open science, such as open access (OA) university presses, data repositories where the items are findable, accessible, interoperable and reusable (FAIR),[7] toolkits for Citizen science etc.
- Lead through actions and not simply through statements.
- Attract resources (in money, staff and time) since a move to open science cannot be made without resource allocation. Such resources can be obtained only if you have a solid strategy and a realistic action plan.

Case studies

Case study 1: competition and collaboration

The authors of this article organized a workshop at OAI11 in Geneva (21–23 June 2019), an event co-hosted by CERN and the University of Geneva.[8]

This workshop aimed to create stepping-stones for building a path for raising collaboration to the same level as competition in a new definition of success in research. It brought together 15 people from eight countries, with various professions: researchers, research administrators, publishers, librarians and representatives of technology companies.

The meeting started with two short presentations from the authors of this article: one from Dr Tiberius Ignat (Director of Scientific Knowledge Services) and the second from Dr Paul Ayris (Pro-Vice-Provost, University College London [UCL] Library Services and Fellow of the Royal Historical Society, UK).

The main message of the first presentation was that without a high level of collaboration, open science is less vibrant, is disadvantaged and is a 'reversible' movement.

Tiberius Ignat also presented his view regarding the hazards of open science. These are:

- failure itself (i.e. not delivering a radical and positive change, not attracting the world's biggest talents nor nurturing diverse communities of explorers)
- becoming an exclusive movement of public research that continues to increase the disconnect with society
- associating 'open' with 'ignore' when it comes to resources that are needed to perform using 'open' methods
- danger of the lack of reciprocity: where some communities benefit from FAIR data, OA and other research output shared globally, while others use the output thus shared without themselves contributing to the global research commons.

Next, he brought the perspective of misdirection to the fore: that open science is about changing patterns of participation. We have become used to hearing that science should be taken back by public institutions, with a certain preference for not-for-profit organizations. Yet, that is misleading! Limiting participation in research activities to just *one* part of society (public and not-for-profit) creates unnecessary isolation and increases the gap between public research and the broader society. Instead, the speaker stressed that:

- great research exists in non-public as well as not-for-profit organizations
- research should no longer be perceived as an elite activity
- distributed participation gives far more public control than a concentration on one particular sector.

Instead of looking to limit participation, we should look to increase and distribute both membership and governance. That could make a much bigger difference in the process of opening up research activities to obtain transparency, integrity, long-term support and agile steering.

In Paul Ayris's presentation, the takeaway message that he proposed to the participants was:

- academically, competition should be against yourself, not really against each other
- no university can be self-sufficient
- emphasis is on multidisciplinary and interdisciplinary research
- universities need to partner with society to show their value
- all these principles are underpinned by collaboration.

This presentation showed what collaboration looks like in practice, at a research-intensive institution. Paul Ayris presented an analysis of the 2019 UCL Research Strategy[9] which contains three references to Competition and 19 equivalents to Collaboration. Among the six principal directions of UCL 2034: a new 20-year strategy for UCL,[10] Principal Theme No. 6 (Delivering global impact)[11] is described as 'delivering global impact through our international activities, collaborations and partnerships'. As an example of European engagement, UCL's triple-track European strategy has included consolidating existing partnerships with European universities, launching a new initiative called the Cities Partnerships Programme (starting in Rome and Paris) and stepping up the University's support for EU research collaboration. In terms of national partnerships, UCL was selected in December 2016 to host the research hub and operational headquarters of the UK DRI (UK Dementia Research Institute), forming the focal point for activity across the six university partners of the UK DRI. The other centres are at the University of Cambridge, Cardiff University, the University of Edinburgh, Imperial College London and King's College London.

Breakout groups

The workshop continued with two breakout groups, where the meeting split into teams to try and identify how new goals and new principles could support researchers and research organizations, if we indeed want collaboration to be valued as equally as competition.

Here are the principles and goals that were suggested:

- share knowledge with the broader society
- create funding systems that encourage young talents to become researchers. Embed collaboration from the early stages of activity as a long-term strategy
- make public engagement part of research proposals and a criterion for funding

- find new resources/extend existing ones to support research ambitions, outside current templates (channels)
- funding through projects should not be the only channel for supporting research activities
- support research programmes more obviously and not simply research projects
- disseminate outputs (publications, data, software) more broadly.

Debate, brainstorming and speed-talk tables

The last part of the workshop included a debate, a brainstorming session and three speed-talk tables, in an effort to find the first stepping-stones towards a path for more collaboration in research activities.

Here are the ideas that were shaped:

- collaboration might build more reproducibility into the system and avoid creating a single point of failure
- collaboration is a sign of research integrity and should be embedded in institutions and in careers
- measure the performance of research funders, who should include in their policies actions towards more collaborations in science and between science and society
- leadership is a necessary element of redesigning research frameworks, with particular importance being given to developing the role of collaboration
- create more stability for research careers. Collaborations could be an important element of such stability
- project competitions have the potential for producing great ideas that simply do not fit into calls for projects. Continue to launch project competitions, but find complementary routes for funding research ambitions
- a DORA-type declaration concerning how research funders should align policies on how they evaluate research and how collaboration plays a role in that evaluation
- encourage pioneering for bringing collaboration up to the same level as competition
- define the constitutive elements of collaboration
- reward collaboration
- the governing bodies of projects/programmes should be multidisciplinary and multisector
- the new landscape should encourage registered reports (that give equal attention to negative results)
- science storytelling is important for open science.

Case study 2: UCL Press

UCL Press[12] is the UK's first fully OA university press. It was started in 2015, building on the foundations of earlier commercial press activity. The purpose in refounding the press as an OA press was to offer support for the UCL academic community in publishing their research outputs as OA to help achieve their research objectives. In the UK the OA agenda was and is being driven by research funders such as the Wellcome Trust[13] (now rebranded as Wellcome) and HEFCE (now part of UK Research and Innovation [UKRI]).[14] UCL, as a global research-intensive university, wanted to develop research platforms which would support UCL's academic activity. Partnership with academics was a prime motivator for the University to invest in systems and processes to support OA publishing.

As CEO of UCL Press, Paul Ayris decided that it should develop publishing strategies for research monographs, textbooks and journals. The activity and the impact of that work in the areas of research monographs and textbooks are described below.

The commercial business model for research monographs was broken.[15] Traditional publishing models had taken insufficient notice of OA or even digital publishing. Between 2014 and 2016 UCL led the Academic Book of the Future project.[16] The results of this project underlined the continuing importance of the book as a unit of output. 'It seems that the future is likely to be a mixed economy of print, e-versions and networked-enhanced monographs of greater or lesser complexity.' Much confusion, however, existed about the role of OA in this landscape.[17]

UCL Press started its OA journey with research monographs and has currently published just over 100 monographs. The most popular platforms on which to access these materials are UCL Discovery,[18] the UCL OA repository, and JSTOR.[19] In terms of the conventional print business model for books, sales over the bookshop counter are falling: 'With sales of monographs falling and the publication of individual titles often based on print sales of 200 or fewer, some now question whether the current model is even viable and for how long.'[20]

While print copies of published outputs are available from UCL Press as print-on-demand copies, this is not the main form of output. Digital OA copy is the form which is easily the most popular. The UCL Press books are held as PDFs in UCL Discovery and made available via the main platforms listed above, supplemented by other routes. In July 2019 download stats stood at 2,167,470, with print sales at 13,643. The ten most downloaded titles are shown in Table 1.

Title	Publication date	Downloads
The Petrie Museum of Egyptian Archaeology	4 June 2015	48,211
How the World Changed Social Media	29 February 2016	338,615
Social Media in an English Village	29 February 2016	77,584
Textbook of Plastic and Reconstructive Surgery	2 August 2016	65,495
Social Media in Industrial China	13 September 2016	100,262
Conservation of Natural and Cultural Heritage in Kenya	7 October 2016	41,945
Fabricate 2017	3 April 2017	46,771
A Conversation about Healthy Eating	3 July 2017	64,359
Social Theory After the Internet	4 January 2018	57,043
Brexit and Beyond	29 January 2018	77,426

Table 1. Top ten downloads of UCL Press titles (to July 2019)

The download figures speak for themselves. The most downloaded book by far is Professor Danny Miller's *How the World Changed Social Media*.[21] Miller was awarded a European Research Council grant to look at the impact of social media around the world and his research team has produced a number of books on this theme, for which *How the World Changed Social Media* is the summary volume.

One of the top ten is a textbook: *Textbook of Plastic and Reconstructive Surgery*, edited by Dr Deepak Kalaskar and others. This documents innovative clinical techniques in burns and plastic surgery. In discussion with the lead author, it was clear that he wanted the textbook to be OA in order to share such clinical practice with colleagues in developing countries, who simply would not be able to afford multiple copies of paper textbooks.

Another finding from the UCL Press stats is the debunking of the idea that OA publication kills paper sales. Although not the primary form of dissemination, the Press is still making significant sales of paper copy, for example over 13,000 in July 2019.

These figures debunk another misconception. Mandates for OA publishing from research funders usually exclude research monographs from their remit on the grounds that it is very difficult to change the current book publishing model. This is certainly the view of Plan S[22] from Science Europe. Yet, the UCL stats suggest the opposite: that OA research monograph publishing is ripe for development.

At the workshop on research practice held as part of OAI 11 in Geneva, the attendees looked at collaboration and sharing as a complement to traditional models of research competition. The theme of sharing and the creation of a global community being able freely to access research outputs is fundamental to the values held by UCL Press. Through the activity of the Press, UCL is able to fulfil its strap-line as 'London's Global University' and to act as a generous partner in sharing its research outputs with the world. These are also the same ambitions as UCL's Global Engagement Strategy.[23] The heat map (Figure 1) shows the impact around the world of the downloads of UCL Press titles. Through the model of OA publishing, UCL has been able to reconnect its research activities in a very real way with communities across the globe. By doing so, UCL is able to share its insights to help discover solutions to the ills which face society – such as global warming, poor health and poverty.

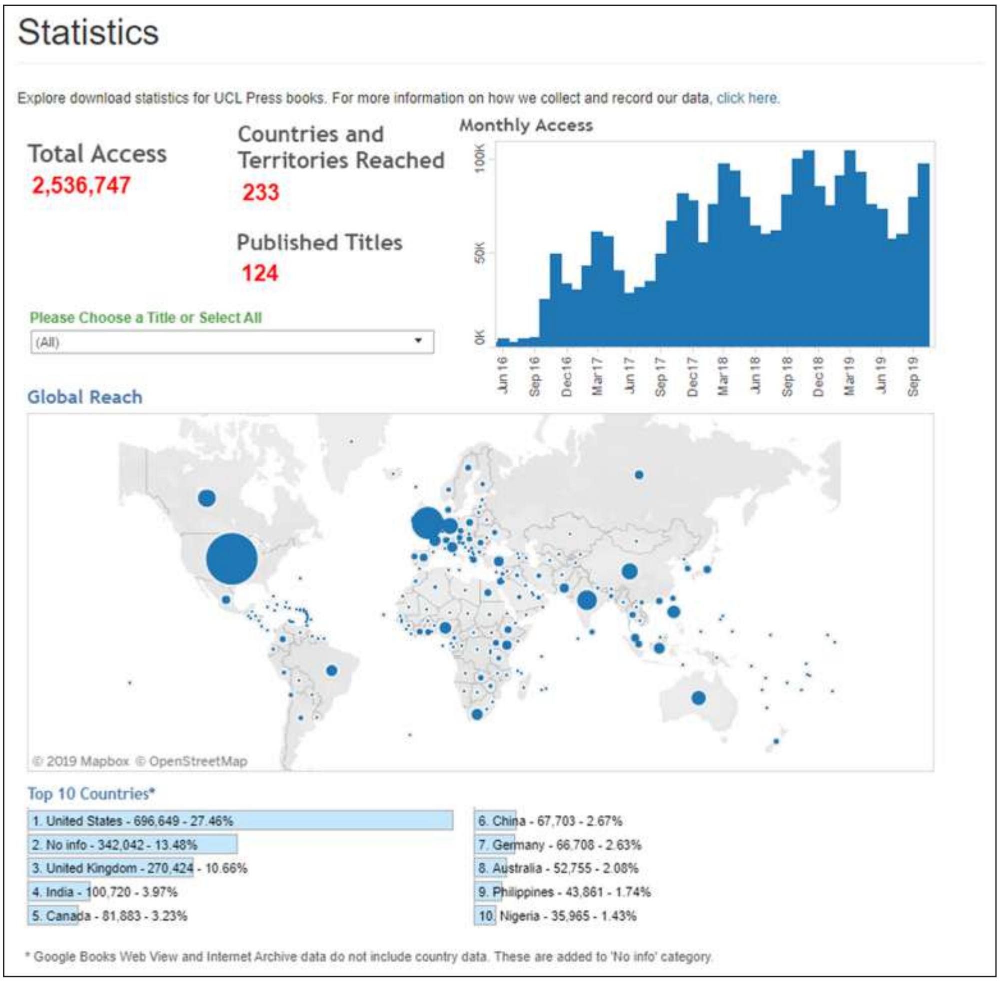


Figure 1. Distribution Map of UCL Press downloads (December 2019)

UCL has been able to develop its concept of sharing in the publishing arena in one further direction. The Press offers 'white label' publishing services to universities who wish to have their own university press but do not wish to invest in all the infrastructure necessary to deliver it. In this way, UCL Press can provide back-end publishing services to universities who want to become publishers. Front-end services, such as commissioning and peer review are the responsibility of the local university. All published outputs are branded with the name of the local university press. Dublin City University is the first European university to avail itself of these services, becoming the first fully OA university press in Ireland.

Case study 3: open data, FAIR data and reproducibility

LEARN

Research data is the new currency in research activity. A useful set of tools and insights on the role of research data was established by the EC-funded LEARN project,[24] which received funding from the European Union's Horizon 2020 research and innovation programme.

LEARN produced a number of important outputs:

- a toolkit of best practice in Research Data Management (RDM)
- a model policy for RDM
- executive briefing on RDM in six languages
- key performance indicators
- 20 RDM best practice recommendations
- an evaluation grid for RDM policies in Europe
- core elements of an RDM policy
- an RDM readiness survey data set.

One of the case studies in the toolkit of best practice looked at levels of preparation amongst researchers in a research-intensive university, UCL, for systematic RDM. The case study built on a wider survey undertaken in 2016 by Miriam Fellous-Sigrist on *UCL researchers and their research data: practices, challenges and recommendations*.[25] Question 61 of the survey asked at what stage of their projects researchers started thinking about RDM. Two thirds of those answering (n = 217) said that they thought about this at the beginning or all the time. The answers from the remaining third were less positive. (See Table 2.)

At what stage of the project did you think about data management?

Timespan	Defined as:	%
Beginning of the project	'Very early on'; 'straightaway'; 'pre-protocol'; 'at the outset' etc.	51
Always	'All the time'; 'Throughout'	16
Project development	'Proposal writing'; 'for ethical review'; planning' etc.	14
Before or after 'data collection'	'Questionnaire design'; 'fieldwork preparation' etc.	4
During the project	'Periodically'; 'halfway through'; '1st year of PhD'	4
Never		4
Late	Also 'Too late'	2
End of project	'At the end'; 'towards the end'	1
Project completion	'Ready for publication'; 'database completion'	1
Ad hoc		1
When a problem occurred		1
	'Not until I took this survey'	1
N = 217		
Free text answers		

Table 2. Results of a UCL survey (2016) on research data management practices (with part percentages rounded up)

UCL's Research Data Repository (RDR)

Open data is key to establishing sharing and collaboration as part of UCL's research mission. With this in mind, 2019 saw the launch of the Research Data Repository (RDR) for open data – data which is not personal nor sensitive and can be shared with a broader community.[26] The position of the RDR in the UCL research system is illustrated in Figure 2.

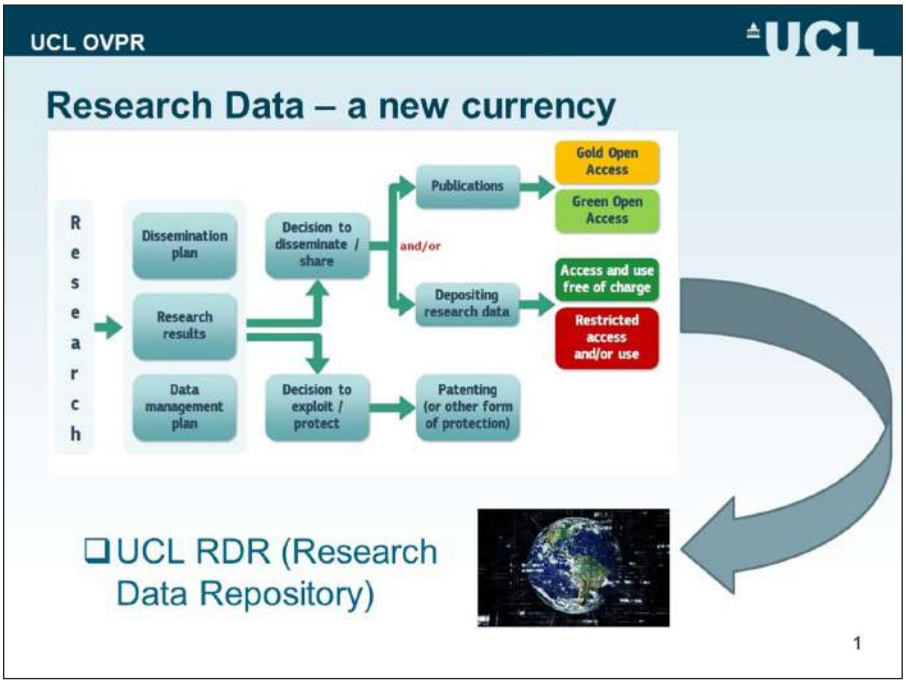
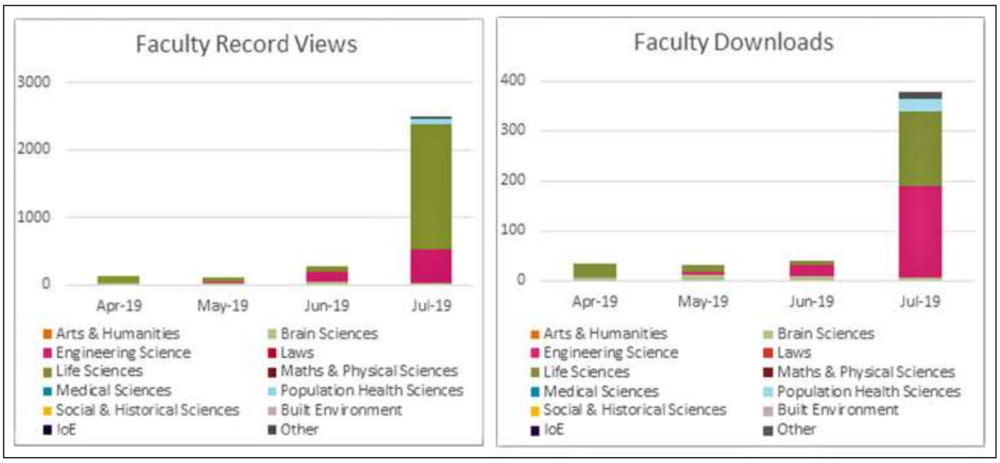


Figure 2. The position of the Research Data Repository in UCL's research system Graphic from H2020 Online Manual[27]

As Figure 2 shows, publications can be disseminated as green OA outputs via the institutional repository or else made available as gold OA outputs. UCL Press would be one such avenue. The RDR serves the same function for research data, enabling UCL to share its research data assets with the rest of the world.

RDR was launched in June 2019, the culmination of a substantial three-year project. Given the short amount of time that RDR has been live, figures for usage are still in their infancy. Nevertheless, the data so far shows that the launch of RDR has made an impact on the UCL research community. The provision can only grow in importance and visibility as research funders increasingly require data curation plans and mandate curation as a condition of grant funding. Where they require open access to publications, they do not (yet) mandate the same for funded research data. Figures 3a and 3b show the monthly number of views and the number of downloads from RDR broken down by each of the UCL's Faculties and Schools.



Figures 3a and 3b. Charts showing views and downloads of research data from UCL RDR[28]

The RDR service also reports on the global impact RDR is making by analyzing record views per country. Figure 4 shows where users of the RDR are based.

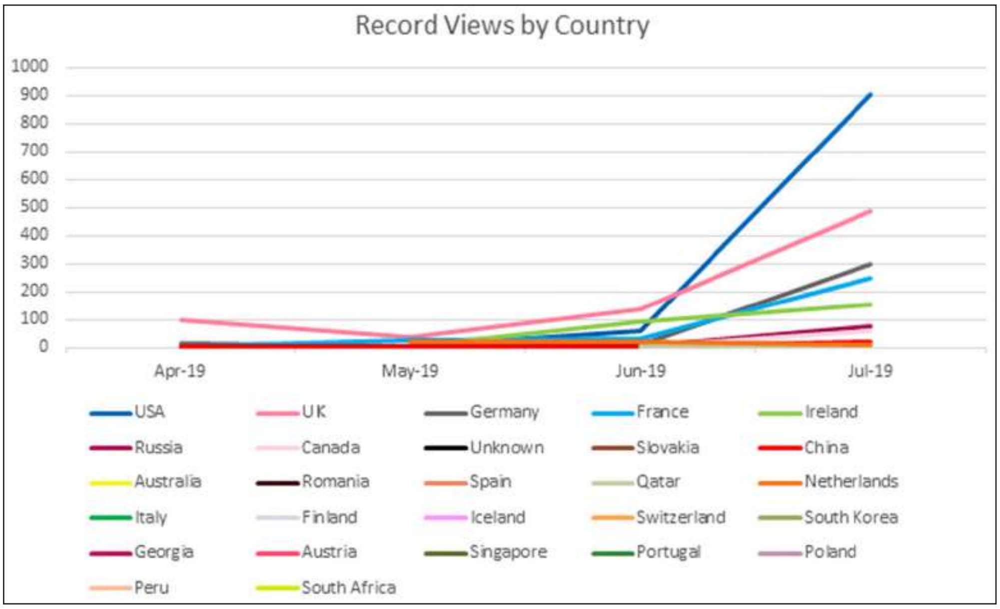


Figure 4. Graph showing record views in RDR by country

The RDR represents a major investment by UCL in open data and is a contribution by one of the world's great research-intensive universities to the open science agenda. It fulfils the aspirations voiced by Professor Geoffrey Boulton in his contribution to the LEARN project, echoing the Accord on Open Data from The International Union of Crystallography:[29]

> 'Publicly funded scientists have a responsibility to contribute to the public good through the creation and communication of new knowledge, of which associated data are intrinsic parts. They should make such data openly available to others as soon as possible after their production in ways that permit them to be re-used and re-purposed.'[30]

This is the position adopted by the RDR. Research data should be 'as open as possible, as closed as necessary'.[31] It is not a mandate for openness. The decision on whether to make data open lies with the research group undertaking the research, but open approaches are strongly encouraged.

'The decision on whether to make data open lies with the research group undertaking the research'

FAIR data

Fundamental to good RDM are the FAIR principles, supporting data that is findable, accessible, interoperable and reusable.[32] Most of these principles concern metadata. It should be noted that FAIR data is not the same as open data. Data can be FAIR, but still not open. One of the challenges in implementing FAIR data practices at institutional level is that FAIR demands significant input by researchers to describe their data.

UCL has taken a measured approach in requiring metadata to describe research data in RDR. The web guidance specifies the following points.

- If you do not need to follow a discipline-specific schema, or funder's recommendations, then we advise you to use the DataCite metadata schema.[33]
- As a general rule, DataCite[34] recommends that your metadata should at least specify:
  - *an identifier* (a DOI)
  - *a creator* (the name and affiliation of the main researchers involved in producing the data set)
  - *a title* (the name or title by which the data set is known)

- ◦ *a publisher* (the name of the entity that holds the data set)
- ◦ *a publication date* (the year when the data set was or will be made publicly available)
- ◦ the *type of resource* you are describing.[35]

FAIR data will underpin the development of the EOSC (the European Open Science Cloud) which is intended to become an 'internet of things'. This point is made forcibly in the EC report *Turning FAIR into reality*.[36] The report makes 27 recommendations, which are grouped into 'priority' and 'supporting' recommendations. The 15 priority recommendations should be considered the initial set of changes or steps to take in order to implement FAIR. Recommendation 10 recognizes the challenge which FAIR principles bring to an institution: 'Steps need to be taken to develop two cohorts of professionals to support FAIR data: data scientists embedded in research projects, and data stewards who will ensure the management and curation of FAIR data.'[37] There are significant financial implications behind this recommendation as, initially, there are extra upfront costs that have to be met. It will be a significant challenge for universities to meet. The Report acknowledges this and Recommendation 18 says: 'Research funders should require data management costs and other relevant costs to be considered and included in grant applications where relevant. To support this, detailed guidelines and worked examples of eligible costs for FAIR data should be provided.' However, not all research is grant funded and so the recommendation alone will not deliver a fully FAIR world.[38]

Recommendation 17 makes an important statement concerning FAIRness and openness: 'Policies should be aligned and consolidated to ensure that publicly-funded research data are made FAIR and Open, except for legitimate restrictions. The maxim "as Open as possible, as closed as necessary" should be applied proportionately with genuine best efforts to share.' This is exactly the position taken by the RDR at UCL.[39]

Reproducibility

Reproducibility is critical to research in certain contexts, particularly in the experimental sciences with a quantitative focus. It forms part of UCL's wider commitment to transparency and rigour in all of its research. UCL recognizes that behaviours in support of transparency and rigour vary considerably across disciplines and methodologies, and encourages researchers to adopt those actions most appropriate to their disciplines.

In the arts, humanities and social sciences, it may be more useful to refer to transparency or academic rigour in the use of research methods and in the whole research process – from the collection of evidence or thoughts through analysis to final conclusions and the publication of findings.

The reproducibility of research methods is required for research to be replicated. This, in turn, is essential in research contexts where findings must be robust and reproducible in order to form a solid foundation on which to build further knowledge.

In research contexts where reproducibility is possible and appropriate, UCL strongly encourages researchers to use measures that support it. These include (but are not limited to):

- *pre-registration* of research studies
- transparent *reporting* of research in line with guidelines[40]
- disclosure of *all tested conditions*, analysed measures and results
- transparency around *statistical methods* (including sample size planning and statistical assumptions and pitfalls)
- use of *preprints*

- carrying out *replication studies*
- publication of *'null' findings*.

Professor Marcus Munafo and others have set out a summary of initiatives that support reproducibility.[41]

UCL is committed to supporting transparency in research and to developing approaches to improve the quality of the research produced. This includes:

- continuing to *support open research* (including through the Academic Careers Framework[42] and the necessary cultural change, as discussed in LERU's policy paper[43] on open science
- the development of *governance processes* to enable research outputs to be *found, accessed, and reused appropriately* when open sharing is not appropriate
- the development of additional *training*, including in *research methods*, and consideration of how to promote transparency in academic teaching
- improving the *sharing of knowledge and best practice* across UCL.

In the autumn of 2019 UCL took steps to implement these convictions by issuing a Statement on Transparency in Research, which sets out the expectations the institution has for researchers relating to transparency and reproducibility at UCL.[44]

Case study 3: citizen science

Citizen science refers to general public engagement in scientific research activities when citizens actively contribute to science, either with their intellectual effort or surrounding knowledge or with their tools and resources.[45] In their 2014 white paper, the Socientize Consortium describes this scientific activity in which participants provide experimental data and facilities for researchers, raise new questions and co-create a new scientific culture. While they are adding value, volunteers also acquire new learning and skills and gain a deeper understanding of scientific work in appealing ways. As a result of this open, networked and transdisciplinary scenario, science-society-policy interactions are improved, leading in turn to more democratic research based on evidence and informed decision-making.

There are several efforts to create a definition for citizen science, one of most recent being proposed by five Austrian authors[46] which triggered a flurry of online discussion and resulted in the publication of a response pointing to the problem that we have in delineating narrow criteria for citizen science.[47] We think that certain criteria and tools could be adopted and employed to create a more inviting environment and to provide access and power to those lay people who wish to engage with scientific efforts. At the same time, this approach should offer trustworthy data and further contributions by researchers. For this, scientists and research support organizations need to design new services and processes like training programmes, assessment, and/or compliance tools that assure high-quality public participation in science.

An example of such recommendations to create support for citizen science projects can be found in LIBER's (The Association of European Research Libraries') Roadmap for Open Science.[48] LIBER recommends designing a triangulation between the library, researchers and the public in which libraries become an active partner that creates support infrastructure enabling responsible conduct and good scholarly practice through guidelines and developing skills for citizen science practitioners.

Citizen science is seen as one of the eight pillars of open science as defined by the Open Science Policy Platform (OSPP) which is one of EC's high-level expert groups. By including it in its definition of open science, OSPP is making a set of recommendations to funders, research performing and research support organizations. Citizen science and all related methodologies should be seen as part of public engagement in science and technology, which is very important for the progress of science. It is opening up new resources for researchers and research organizations. Citizen science also has important roles in developing a scientifically literate society and in providing a solid entry point for people who are not trained as scientists, to support them in suggesting important topics for the research agenda.

Successful citizen science projects involve the public from the early stages of research and communicate with the general population about the progress that is being made at the frontiers of knowledge. Managing the transition to a new culture of open science means, from the perspective of citizen science, seeing a public contribution not only in the area of enhancing scientific effort (by collecting data, being involved in public outreach, etc.), but also in addressing societal needs by creating scientific evidence that supports public decision-making. In this way, citizen science can contribute to the education of the general population and increase society's scientific literacy by developing networks of professionals and amateurs that can accelerate discovery.

The quality of data in citizen science projects remains an important element to be managed in the new landscape of open science. There is enough evidence to show that, with the right training programmes, the data collected by citizens passes quality control at expected levels.

One example in which training played an important role is Capturing our Coast (CoCoast),[49] a project which trained over 3,000 volunteers (between 2015–2018) to gather data to help scientists understand in more detail the species that live on UK coasts. As an interesting fact, the volunteers in this project have produced the first record of a Xaiva biguttata crab in the UK since 1956.

Another project that involved a great number of volunteers and in which 90% of the data passed quality control is Curieuze Neuzen.[50] This project shows another determinant factor of success for citizen science projects: disseminator power. With over 56,000 registered volunteers, around 20,000 sensors were distributed in the Flemish region of Belgium to monitor air quality. For disseminating this number of sensors, the project partnered with a local newspaper which undertook the distribution of measurement kits.[51]

The impact of citizen science is measurable, and it is probably more diverse than traditional scientific methods. Here are two examples, to illustrate the footprint of citizen science in society.

Firstly, researchers at the University of Washington in the USA quantified the value of citizen science activities in biodiversity fields.[52] They surveyed 388 US projects and found that the projects embraced 1.3–2.3 million citizen scientists, who provided US$667 million–2.5 billion worth of in-kind contributions to those projects, annually. The economic worth of citizen science is enormous.

Secondly, Transcribe Bentham (an award-winning[53] participatory initiative launched in 2010 at UCL), which engages the public in the online transcription of Jeremy Bentham's work, has been cited so far in 39 monograph chapters or articles and 13 books.[54] Peer-reviewed scholarly communication is a natural part of citizen science which is also opening additional communication opportunities in lay language for society as a whole. The latter, a separate dimension of science communication, is very important now for consolidating a place for science in an era when expert opinion is targeted/ignored by populist discourse.

For these reasons alone, European institutions are taking citizen science seriously. Table 3 provides examples of European policy-making support for citizen science. The next step is to develop and support implementation programmes and to create rewards for scientific activities that produce engagement with the public.

Name	Description	Significance
The European Association of European Research Libraries (LIBER)'s Open science Roadmap[55]	This Open Science Roadmap was established by LIBER in 2018. Recommendations from this roadmap broadly endorse libraries as partners in citizen science, guiding the development of the field.	This roadmap emphasizes the importance of citizen science as part of cultural change.
LIBER Citizen Science Working Group[56]	Launched in March 2019, the working group is intended to explore, among other questions, what the role of libraries will be in terms of citizen development, education, and instruction, especially relating to citizen science.	This working group is intended to connect colleagues across Europe to explore citizen science opportunities and best practices.
The League of European Research Universities (LERU)	Comprises over 23 research-intensive European universities. They published a paper[57] that analysed trends in citizen science and provided guidelines that ranged from raising awareness to developing assessments for citizen science in research funding and evaluation processes.	Demonstrates institutional support for citizen science at the university level.
Science Europe	Released a briefing paper on citizen science in 2018,[58] endorsing the 10 key principles of citizen science developed by the 'Sharing best practice and building capacity' Working Group of the European Citizen science Association.[59]	Represents major research funding and research performing organizations across Europe.

Table 3. Examples of European policy-making support for citizen science 2018–2019

LIBER took a leading role in creating support services for citizen science at the library level by establishing a working group dedicated to this area of open science. This working group has several goals:

- goal 1: to initiate and/or participate in one research project by October 2021
- goal 2: to staff the working group until the LIBER Conference 2020
- goal 3: to sign two partnerships with outside organizations by October 2021
- goal 4: to deliver by June 2020 a template (or a suite of templates) with accompanying advocacy for a 'Single Citizen Science Contact Point' that could be implemented in research libraries
- goal 5: to organize and deliver a webinar by July 2020
- goal 6: to create a librarian's guide to citizen science, building on the similar guide created by SciStarter and the State University of Arizona, by July 2020.

These goals will be followed through six strategic directions, which are:

- projects – referring to goal 1
- staff development (recruitment, training and skills) – referring to goal 2
- partnerships and participation – referring to goal 3
- building citizen science infrastructure in libraries (building a template for Single Citizen Science Contact Points) – referring to goal 4
- advocacy and policy – referring to goal 5 and goal 6
- creating a librarian's guide to citizen science, referring to goal 6.

LIBER's initiative is in line with the efforts of Arizona State University and SciStarter (an online citizen science hub), which jointly created the *Librarian's Guide to Citizen Science*,[60] giving practical guidance to interested institutions. This guide is just one outcome of an ongoing project in the USA entitled 'Libraries as Community Hubs for Citizen Science', which demonstrates the potential for libraries as partners in the citizen science field. The project team includes SciStarter, Arizona State University faculty, researchers, practitioners and evaluators, librarians/staff, citizen science project leaders, web designers/developers and advisors. They collaborated to:

- develop and evaluate citizen science toolkits available for and through the public library partners
- create associated resources to train, support and communicate with librarians and citizen scientists.

A practical way to approach citizen science at institutional level is by establishing a Single Citizen Science Point of Contact, a recommendation which is also highlighted in the aforementioned *LERU Roadmap for Open Science*. We propose an attractive name for such points of contacts in order to make them familiar among researchers, the public and other staff: BESPOC (Broad Engagement in Science, Point of Contact). A BESPOC could typically provide:

- a platform on which to build and continuously update the institutional policy for citizen science, including a concordat of interest between involved stakeholders (laboratories, PR offices, safety compliance offices, scholarly communication offices, data centres, training centres, etc.)
- information about citizen science activities in the respective institution
- partnership frameworks between units and departments belonging to the respective institution or with third party organizations
- collection of templates for citizen science activities (data sheets, protocols, training methods, checklists, reports, evaluation forms, etc.)
- entry points and dissemination points for scholarly and lay communications, in relation to an institution's scientific activity
- information about community-building activities
- a point of reference to help scientists embed citizen science into grant proposals
- a gateway for the public to propose research projects.

An example of a strategy that embeds citizen science activities at institutional level, opening the possibility of establishing a virtual BESPOC, is the UCL Library Services Strategy 2019–22.[61] UCL Library Services has identified key priorities for citizen science activity and plans to embed these in a pan-UCL programme. Outreach activities to new communities should become embedded in the life of the Library; and citizen science is a new outreach activity, where the citizen engages with research agendas. One of the key actions of this strategy is to create a virtual Office for Open Science, where a BESPOC could be placed.

> 'Open science is a means by which collaboration, sharing and openness can be embedded into research activities'

Conclusion

The main conclusion of this article is that if research organizations can support collaboration alongside competition as part of their research activity, benefits will follow. Open science is a means by which collaboration, sharing and openness can be embedded into research activities. A move to embrace open science requires a culture change at the institutional level and a series of actions to deliver that change.

This article has looked at four areas of open science and identified case studies of best practice where change is happening:

- competition and collaboration
- UCL Press as an alternative OA publishing platform
- open data, FAIR data and reproducibility
- citizen science.

The case study on UCL Press shows the impact which full OA publishing can make, embracing areas such as the arts and humanities, with very significant benefits. Research data is the new currency in an open science landscape. To encourage researchers to share their data, making it open where possible, institutions can create their own curation platforms which enable this sharing to take place. Reproducibility and transparency are important elements of research integrity in open science, and UCL has underlined its commitment to such values by issuing its Statement of Reproducibility and Transparency. The final case study is on citizen science, and it is clear that a number of leading European organizations who have embraced the concept are now working to deliver citizen science solutions for this vital aspect of societal engagement.

Open science is a new way in which research is performed, evaluated, rewarded, disseminated and curated. Europe is playing a leading role in advocating for open science practices and platforms. Such work needs to continue to deliver the transformation and benefits that open science promises.

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Abbreviations and Acronyms
A list of the abbreviations and acronyms used in this and other *Insight*s articles can be accessed here – click on the URL below and then select the 'full list of industry A&As' link: **http://www.uksg.org/publications#aa**

Competing Interests
Tiberius Ignat is the director of Scientific Knowledge Services and he acted in 2019 as an unpaid member of the organization committee for OAI 11, a CERN-University of Geneva workshop. He is also a member of LIBER Citizen Science Working Group where he leads the 3rd Strategic Direction ('Partnerships'). Scientific Knowledge Services offers, on request, consultancy related to open science and Tiberius Ignat might take assignments in that sense.

Paul Ayris is Pro-Vice-Provost (UCL Library Services) in charge of the UCL family of libraries and responsible for the development of open science principles and practice across UCL. He is also CEO of UCL Press, the UK's first fully OA university press. He is co-chair of the LERU INFO community, and chaired the writing committee for the LERU Roadmap for Open Science. He chaired the Scientific Committee for the OAI 11 meeting (2019) of the Cern-Unige workshop on innovations in scholarly communication. He is also the former President of LIBER and currently chairs the LIBER Citizen Science Working Group. All these roles outside UCL are pro bono and are unremunerated. He was also principal investigator for the EC-funded LEARN project on RDM.

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RESEARCH ARTICLE

Expanding the actions of Open Government in higher education sector: From web transparency to Open Science

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Abstract

Universities have been pressured by governments to change their way of acting and to be more responsible with the requirements of social development to face the challenges of globalization. To this end, universities must use the principles of Open Science, to allow them to be more transparent regarding the dissemination of scientific results. The purpose of this paper is firstly, to determine the progress made in Open Access policies made by the best-ranked universities regarding ARWU. Secondly, to examine influencing factors that enhance the level of openness in researching, in particular, "transparency", "reputation", "participation", "funding", "foundation" and "size". The main results show that those private and older universities, best-ranked in terms of excellence researching and those that have been gradually adopting Open Government policies concerning the dissemination of information through institutional web pages and social participation, are the most interested with complying the recommendations established by the authorities of the Open Science projects.

Introduction

The opening of the data and its reuse is the new vision towards the collaborative Open Government style in the organizations [1–3]. In this sense, universities have been pressured by governments to change their way of acting, to be more responsible with the requirements of social development, and to face the challenges of globalization [4]. Especially, in the context of research and exploitation of their results, being unique to produce, transmit, and disseminate knowledge [5]. As De Blasio [6] notes, digital platforms, institutional repositories, or participatory portals stimulate continuous dialogue and promote knowledge and collaboration processes. Thus, the principles of Open Government allow them to be more open, transparent, efficient, responsible, and collaborative [7].

The concept of Open Government goes back to the 50s [8], although until nowadays there is no consensus on its dimensions [2, 3]. Most of the literature on Open Government coincides with three fundamental pillars established by Obama [9], which are transparency, participation, and collaboration [10, 11].

Competing interests: The authors report no conflicts of interest.

In addition, Open Government in broad terms is based on collaborative relationships between the institution and its stakeholders [12]. It permits to access the information, to know the actions of the institutions and, therefore, to participate in decision-making [13]. Moreover, facilitates the reuse of the data without any barrier, especially economical one [2, 14]. In this sense, Open Government could be considered the "many to many" information and knowledge channel [15 p. 491].

Under this trend, the opening of the government in universities has become a medium-term key factor for its legitimacy as it provides greater transparency, improves accountability, and satisfies different needs of the society in general and, consequently, has a positive influence in universities'reputation [7].

Thus, the emerged concept of Open Government has been the phenomenon that attracted much interest from researchers in recent years, mainly focusing on web transparency and social participation [2]. However, Open Science and its main extension towards Open Access, framed within Open Government initiatives, is less studied. Therefore, this paper focuses on the focal pillar that supports the principles of Open Government applicable to the high education and research institutions (Fig 1).

As Moedas [16] establishes, science must be open, collaborative, and done with and for society.

According to Gezelter [17], the main objectives of Open Science are transparent methodology, reusability of scientific data, accessibility to scholarly communications, and platforms to facilitate scientific collaboration. In this line, scientific collaboration allows opening the science to all levels of society [18]. Therefore, this openness undoubtedly facilitates progress in the dissemination of knowledge unlimitedly through collaboration on information and digital platforms [19]. Furthermore, it helps to guarantee the quality of the research and the rigorousness of the academic process [20].

Given the previous literature, most of the research deals with theoretical aspects of this way of scholarly communication, so particularly linked to universities [21, 22]. Although today, there is little tendency to share research data in universities [19], Open Access to publications has increasingly positioned as an option for scientists to give visibility to their research [23, 24]. Mainly, the literature at this respect focuses on theoretical aspects of Open Access, explaining the rationale for open initiatives [25]; literature review on the academic, social, and economic impact of Open Access [26], or developing measures of the effect of Open Science collaboration on research and innovation [27].

Others describe indicators to track openness in publications [28]; empirical studies on the collaboration of science and the private sector [29]; data sharing factors [30, 31], or different types of Open Access in various university contexts [32]. Besides, Leiden Ranking has been created based on Open Access indicators [33] or initiatives such as the ranking of Open Access repositories [34] which offers partial information on the share of Open Access availability at

Fig 1. Open Government framework in high education and research institutions.

https://doi.org/10.1371/journal.pone.0238801.g001 the institutional level. The literature on the factors that affect the level of Open Access policies in universities is practically non-existent.

Due to the lack of empirical literature at a global level of Open Access, this paper presents two main objectives. Firstly, to analyze the level of Open Access policies followed by the best-ranked universities. Secondly, to explore the influencing factors of these policies and determine whether the universities, which have achieved better evolution in transparency and participation are getting more progress at Open Access level. The Academic Ranking of World Universities (ARWU) was chosen to gain a global perspective of the possible trends. In particular, the initiatives of Open Access of the top 100 universities were analyzed.

The findings of this study aim to contribute to both the existing literature as well as to identify managerial implications for universities. Therefore, from an academic perspective, this paper seeks to contribute to the research on Open Government. Specifically, to expand the literature focused on Open Science in the higher education sector regarding the level of Open Access policies implementation and its relationship with other dimensions of Open Government. In addition, it can also provide fresh insights about the influencing factors that can lead to greater use of universities' digital platforms as the channels for improving and facilitating access to scientific information for their different stakeholders.

Moreover, from a practical standpoint, the analysis of the level of Open Access achieved by the top universities in the world can be used as a benchmark by other universities. This study can help university managers to follow the trends of Open Access in the best-ranked universities to reduce barriers to access the literature and lead to a scenario with more computers stage, better connectivity, and technologies. In this sense, this could allow improving and/or developing a more efficient implementation program to advance knowledge.

To achieve the aforementioned objectives, this study is structured in six sections. Following this introduction, the second and third sections provide literature related to the implementation of the Open Access and its influencing factors. The next section details the methodology applied. The fifth section presents the obtained results, and finally, the most relevant conclusions and implications of this research are exposed.

Open Science initiatives in universities: Open Access

Horizon 2020, the new European Framework for research, and innovation is boosting Open Science to promote scholarly communication [35]. After the publication of the "Open Innovation, Open Science, Open to the World" the European Commission, collaborating with the key stakeholders, has been developing new structures to adopt this new vision of the openness of science [36]. For instance, the "Open Science Policy Platform" [16].

As a consequence of these initiatives, similar policies have been developed and issued in other geographical contexts as "A recommendation on Open Science" [37]; "Open and inclusive collaboration in science: a framework" [38]; "Open science by design" [39], G7 Working Group on Open Science [40] or "Business models for sustainable research data repositories" [41].

The main objectives of Horizon 2020 are to establish mandatory access to scientific publications generated by European funds and to recommend the opening of research databases, which in the end will have to be open by default [36]. In this sense, the European Commission has established a Fair Data expert working group to address the policy and cultural and technological changes facing the opening of science [42]. According to this, Burgelman et al [36] affirm that these policies seek to improve collaboration and engagement of science with society.

Fig 2. Open Access framework based on the European Commission.

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Horizon 2020 refers to Open Science as "The transformation, opening up and democratization of science and research through ICT, with the objectives of making science more efficient, transparent and interdisciplinary, of changing the interaction between science and society, and of enabling broader societal impact and innovation". Consequently, scientific communication can reach anyone with an Internet connection, especially since the social impact is important for developing countries [26].

In addition, OECD [43] highlights the obligation to make publicly funded research accessible through digital formats. In this way, Open Science offers a new approach to the scientific cycle, based on cooperation and dissemination of knowledge using new digital technologies as tools that could boost collaboration [16]. Therefore, this initiative could provide greater accountability, enhance efficiency, and help to face the challenges of general interest [24, 43].

Moreover, Open Science is a broader practice and often referred to as an "umbrella term", including different aspects of the scientific cycle, highlighting among them Open Research Data and Open Access to publications, on which this study is focusing [18, 22, 38]. In this respect, the European Commission [44] has established the framework (Fig 2) and guidelines on Open Access both to research data and to scientific publications.

In recent years, both governments and funding agencies have strived to consolidate an open research agenda to support Open Access [45]. Especially concerning to publicly funded research [20]. In this sense, different Declarations and Statements have been developed, for instance, the Berlin Declaration [46], the WSIS Declaration [47], the Budapest Declaration [48], or the Public Library of Science [49]. In this respect, Piwowar et al [50] indicate that the US National Institute of Health, the European Commission, the US National Science Foundation, or the Wellcome Trust, among others funding institutions, increasingly make Open Access to the obtained results mandatory. According to the Registry of Open Access Repository Mandates and Policies [51], there are more than one thousand different policies, recommendations, and mandates on Open Access and, in particular, more than eight hundred related to universities and research institutions.

Previous literature highlights that, especially, the universities of Europe and the United States have made an effort to open up the science more than the rest of the world [32]. In this sense, the Association of College and Research Libraries [52] states that the United States Government is taking proactive actions in the same direction as the European Union to adopt measures that require its funding agencies to open scholarly communication. However, for a successful implementation of such policies, adequate infrastructures were necessary, for example, the Open Air platform has been developed, to manage and monitor the European public-funded scientific communication [45].

According to the Budapest Declaration [48], the principles of Open Access defend "free availability of (scholarly) literature on the public Internet, permitting any users to read, download, copy, distribute, print, search, or link to the full texts of these articles, crawl them for indexing, pass them as data to software, or use them for any other lawful purpose, without financial, legal, or technical barriers other than those inseparable from gaining access to the internet itself". Although it is important to highlight that "free" is for the end-user of the research, since Open Access involves different subtypes such as Gold, Green, Hybrid, Libre, Gratis, or Black [50]. However, this literature review focuses on the Green and Gold types for representing the largest groups of Open Access publications [32] and for having a greater relevance to the main objective of this paper.

The Gold way could be considered when authors submit their research to Open Access journals, which give immediate visibility to the online article. Two important aspects have to be discussed under this modality, the copyright and the article publication costs (APCs). On the one hand, the copyright is generally protected by Creative Commons (CC) licenses, which are applied within the legal framework and help authors to maintain control over their research [53]. These open licenses generally impose few restrictions and offer six different models, being CC BY and CC BY-SA "free license" [43]. In this line, McKiernan et al [54] indicate that retain author rights and control reuse with open licenses, fosters collaboration. Even so, everything under license can inhibit scientific communication [38]. On the other hand, depending on the business model they follow (for profit or not for profit), the APCs are covered either by the authors or are publicly sponsored [43]. Among the largest Open Access journals are the Public Library of Science, Biomed Central, or Springer Open Choice Publishing, for instance [43].

Regarding the Green-way, it refers to the authors' self-archiving the preprint or postprint versions of their articles. Usually, they provide access to the research through Institutional Repositories or their webpages. Most of the papers published under this modality do not meet the rigorous definition of Open Access, since they imply a period of the embargo as they are first published through traditional channels (journals under subscription fees) and do not extend reuse rights [43, 55]. This goes against the principles of Open Access and confronts the Green-way with the immediacy of the Golden path definitely [56].

In general terms, the previous research agrees that half of the literature is Open Access, where English universities are the most proactive in the implementation of these policies [32, 57]. However, in the last years, university budgets have undergone changes, making it difficult to access all the journals and causing the loss of impact for many of them [16, 58]. Thus, the Golden-way has managed to position itself in front of the Green-way. In this regard, the literature agrees that open articles have a greater impact compared to those that cannot be accessed immediately, the former achieving more citations [50, 58, 59]. Piwowar et al [50] and Peroni et al [59] find that this increase is around 18 percent and between 9–30 percent, respectively. In the same line, McKiernan et al [54] and Wang et al [60] indicate that Open Access articles receive more attention in Social Media. In addition, Abadal et al [61] in their qualitative study find that publishers think that Open Access allows the better dissemination of content, but does not influence its quality.

Furthermore, Yang and Li [62] discuss the lack of peer review in some of the articles of the Golden-way, which increases the lack of confidence, especially in the aspects of plagiarism. Moreover, Dawson and Yang [63] argument that the publications deposited in Institutional Repositories avoid such problems, since they pass rigorous peer review processes, although they present embargo problems to reach greater immediate visibility. However, other studies offer contrary annotations, indicating that Open Access journals are also very exhaustive in their peer reviews [54].

Nevertheless, journals increasingly are giving the author the option to self-archive. In this line, as the recommendations advance towards the official mandate, Open Access Institutional Repositories have become a tool that is settling on the foundations of Open Science [23]. This is confirmed by Piwowar and Vision [64], who found evidence that publications with open databases in repositories get about nine percent more impact than those, which do not reveal their raw data.

Finally, Open Access culture creation is another important aspect of this issue, where employees play a key role [65]. Libraries and librarians are the most important in defending and supporting Open Access policies [25]. Although most libraries do not discuss copyright issues with commercial publishers, leaving it to the authors [63].

Explanatory factors of academic communication

The theoretical framework for this study is drawn from the dissemination of information and communication management since Open Access emerges as a response to minimize the economic barriers of the traditional system of scholarly communication [66]. This vision being broad, different theories can be considered to explain the dissemination of scientific results from different points of view. Fundamentally, Open Science initiatives seek the informative satisfaction of the organization's stakeholders, both internal and external. In this sense, among the theories that can best explain the commitment of stakeholders in the websites and digital platforms of an organization are the Theory of Stakeholders [67], the Theory of Dialogic Communication [68] and Legitimacy Theory [69].

Based on these theories and previous literature, the following factors have been selected in order to know the degree of execution of Open Access policies: organizational size [70, 71]; reputation [72, 73]; and age [74]. Other factors to be considered include transparency and public participation [75, 76]. This paper examines the factors most appropriate for its objective, considering the following: "transparency," "participation," "reputation," "funding", "foundation" and "size."

According to the stakeholder theory [67], organizations should achieve their objectives with consideration of different stakeholders. In this regard, all entities should inform their stakeholders about the activities carried out [77]. In particular, in the field of universities, after the cases of fraud in recent years, universities following the FOIAs have made an effort at first to access information, that is, transparency. For later, to continue advancing in line with the social demands of the academic world for greater accountability in Open Science [24]. In this respect, the Open Access approach is an efficient way to give diffusion to the scientific results obtained in universities. Cerrillo-i-Martínez [76] states that it is not enough to offer a large quantity of information to satisfy the demand of the stakeholders since the quality of the content and access to it through different mechanisms play an important role. These could be the institutional repositories of the universities that are dedicated to managing Open Access policies. Considering this, the following hypothesis aims to demonstrate the transparency effort to reinforce the level of Open Access in universities:

H1: *Achieved transparency positively influences the Open Access level in universities*.

The stakeholder theory points out that long-term organizational outcome is determined by stakeholder relationships [78]. Within the context of universities, academic outcomes are one of the prestige indicators of social interest [72]. Such reputation or prestige is achieved by improving different organizational systems in order to position the university in the different university rankings [79], which measure the quality of research and education [80]. These achievements could affect different groups: students, both current and future, in choosing their studies; employees in the hiring process; and even the process of raising funds or undertaking reforms [81]. Consequently, it would be reasonable to expect that those leading universities would be the most incentivized to use Open Access as mediums to inform their stakeholders of the entity's excellence in research. Therefore, the following hypothesis is:

H2: *Reputation positively affects the Open Access level in universities*.

According to the theory of dialogic communication, Kent and Taylor [68] have developed a framework that explains how it is possible to build and maintain online relationships between an organization and its stakeholders. This dialogic communication theory points out that improving online interactivity creates social relations, increases confidence in the entity, and gives greater satisfaction to the users of these interactions [82]. In this sense, as the new indicators for scientific communication are through Web 2.0 [83] it can be expected that greater participation in social media can influence the higher levels of Open Access in universities. Thus, the following hypothesis is:

H3: *Participation positively influences the Open Access level in universities*.

Moreover, Suchman [69] posits that legitimacy is created subjectively as it strongly depends on the perception that the audience has of the organization. Likewise, the author argues that "legitimacy management rests heavily on communication" [69 p. 586]. Therefore, organizations are interested in strategies that can boost the level of participation and collaboration between the firm and the society, using ICTs in order to ensure stakeholders' comprehensibility and approval of the activities they carry out [84]. At this point, the pressures, in terms of data sharing, that can be received by scientists of public universities from funding agencies can positively influence the attitude towards the dissemination of their scientific results [31]. In this sense, the scientific community increasingly agrees to open publicly funded publications for the interest of stakeholders [85]. Further, the journals are also inciting academics from public and private universities to open both, publications and research data [24, 86]. Thus, universities to lead with this requirement should increase the Open Access policies, in order to gain legitimacy and efficiency. Considering above, the following hypothesis is:

H4: *Funding influences the universities' Open Access level*.

Given the demand for greater legitimacy, efficiency, and transparency [87], older institutions must use the disclosure of information via different digital platforms, not only to improve the visibility of their actions but also, as part of their differentiation strategy [88]. Concerning higher education, Gallego-Álvarez, Rodríguez-Domínguez, and García-Sánchez [89] and Garde-Sánchez, Rodríguez-Bolívar, and López-Hernández [90], consider that organizational age is a relevant factor that should be taken into account when analyzing the access to data of universities. Likewise, Garde-Sánchez et al [74] pointed out that the oldest universities, which have a greater experience in running the organizations than their younger counterparts, are more likely to implement their communication policies better. Consequently, the next hypothesis proposed is the following:

H5: *Foundation negatively affects the Open Access level in universities*.

Size is usually related to greater visibility and influence of the organization in society and thus to greater exposure to public scrutiny [91]. Concerning the public sector, Serrano et al [71] point out that the interest of the government to make the information accessible increases according to the size of its population. In the private sector, size is also considered an influencing factor in relation to information disclosure [92]. Conferring to the legitimacy theory it is posited that larger universities would be more interested in offering content with relevant and demanded information in order to improve their reputation, image, and relationships with their stakeholders [74]. Even more, Open Access could be a channel to help developing the correct strategies of Open Government. Thus, it can be assumed that the larger universities have a greater need to share the outcomes of their research. Taking into consideration that larger universities are more likely to adopt open initiatives, the following hypothesis is proposed:

H6: *Size positively affects the Open Access level in universities*.

Materials and methods

Sample

The sample includes universities of the ARWU's top 100, commonly known as Shanghai Ranking. Universities are ranked according to several indicators of academic or research performance, including alumni and staff winning Nobel Prizes and Fields Medals, highly cited researchers, papers published in Nature and Science, papers indexed in major citation indices, and the per capita academic performance of an institution. The ARWU is considered one of the most influential and widely used international ranking system of its class because of its solid and transparent methodology [93, 94]. Due to the lack of the necessary data to carry out the explanatory analysis, the final sample consists of 71 universities. The period of the study was September of 2019.

Analysis of Open Access policies in the best-ranked universities

To achieve the first objective the Open Access initiative in the top universities was analyzed. This analysis is based on Melibea [95], directory, and estimator of institutional Open Access policies of scientific production. This tool allows to compare the content of policy between universities. First, the index related to Open Access policies using indicator estimated by Melibea was elaborated. It is based on the values assigned to a set of indicators (S1 Table), weighted according to their importance in the fulfillment of each aspect analyzed. Second, questions regarding Open Access policies and, according to Melibea, have been sent to those responsible for this issue of the universities that were not available in the directory.

Explanatory analysis of Open Access

To identify the causal relationship between Open Access policies followed by the top universities and the selected factors six hypotheses were proposed. Assuming linearity in the relationships between the variables studied and, in line with previous literature, multivariate linear regression was used [74, 94]. This is an appropriate technique to identify whether certain independent variables explain a continuous dependent variable [96], particularly if certain organizational factors have explicative power on the level of Open Access policies achieved by universities. The dependent variable "Open Access" (OA) was measured using the index of Open Access developed by Melibea, and the independent variables are shown in Table 1.

Table 1. Independent variables.

FACTOR	MEASUREMENT	EXPECTED RELATIONSHIP
Transparency (TRA)	Global Transparency index developed by Saraite-Sariene et al [97] and updated.	**H1+**
Reputation (REP)	The position in Academic Ranking of World Universities (ARWU).	**H2+**
Participation (ENG)	Global Engagement index developed by Saraite-Sariene et al [98] and updated.	**H3+**
Funding (FUND)	Dummy variable, noting 0 in the case of public universities and 1 for private ones [89].	**H4+/-**
Foundation (FOUND)	The foundation date of the university [99].	**H5-**
Size (SIZE)	No. of students [74].	**H6+**

Source: own compilation based on literature review

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Taking all of this into consideration, the proposed model for the dependent variable is the following:

$$OA_i = \beta_1 * TRA_i + \beta_2 * REP_i + \beta_3 * ENG_i + \beta_4 * FUND_i + \beta_5 * FOUND_i + \beta_6 * SIZE_i + \mu_i,$$

where OA is the dependent variable, β the parameters to be estimated, TRA, REP, ENG, FUND, FOUND, and SIZE different independent variables, μ the classic disturbance term; and i refers to each of the universities considered.

Results and discussion

Open Access index in the best-ranked universities

The descriptive analysis (Table 2) shows that the level of adoption of Open Access policies is around 47 percent in general terms. Delving further into the analysis of Open Access followed by the universities we can observe that Oxford University is the one that has shown the greater efforts in adopting Open Access policies, followed by Chicago, Illinois at Urbana-Champaign, or Technical Munich universities (S1 Table). Among the universities that did not actively adopt the recommendations of the competent authorities or the implementation of these initiatives is in the development process are Tokyo, Toronto, Peking, or Nagoya universities among others (S1 Table).

A more graphical view of the best-positioned universities in adoption and monitoring Open Access policies is provided in Fig 3.

Besides, focusing on S1 Table and regarding the "Open Access Policy" only 44 percent of the universities analyzed are applying more rigorously the guidelines proposed by the competent authorities. This is reflected in "Mandatory Compliance" since only 4 percent of the universities allow their staff to be exempt from the deposit and immediate open access without reviewing case by case. Concerning "Deposit Versions", author's final draft along with the publisher's versions are the options of more than half of the universities studied (52%), with the "Deposit Deadline" "as soon as possible" being only 8 percent. For the "Embargo Period", it should be noted that the Green-way and the Golden one get into conflict, 20 percent of universities adapt this problem to the publisher's stipulations.

Continuing with the "Copyright Reservation", 40 percent of universities have established that authors maintain copyright, albeit with certain annotations. In addition, the analysis reveals that the deposited material is not used internally, which, in a certain way, confirms that the use and deposit of the raw data of investigations, for example, is in its infancy and many of the institutions of higher education do not mention or are starting to adapt platforms for its reuse. Concerning the "Requirement of Dissertation Deposit", both mandatory character and recommendation achieve around 30 percent.

Finally, it should be highlighted, that the questions on mandatory compliance, deposit deadlines and embargo period are the issues that are less disclosed; more than half universities do not provide information in this regard.

Table 2. Descriptive statistics.

Variable	N	Min	Max	Mean	SD
Open Access level	71	1	100	47	32,54

Source: own compilation

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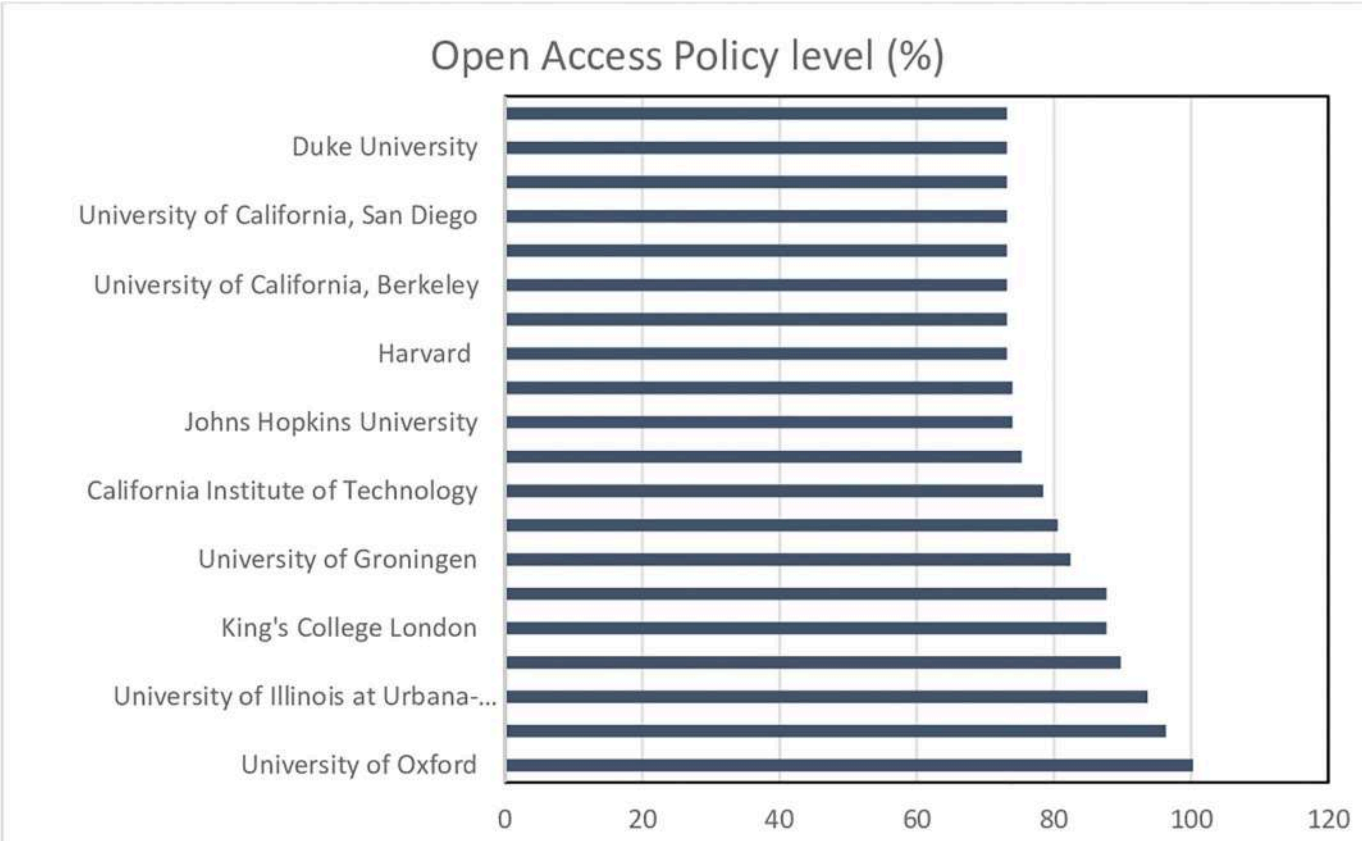

Fig 3. Open Access Policy level of the top 20 universities.

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Explanatory analysis

The second phase of this study consisted of analyzing the influence of specific factors on the level of Open Access for universities. To this end, a multivariable regression analysis was used. By using Fisher's critical value ($F = 25.52$; $p<0.01$) linearity of the regression was confirmed. After confirming the rest of the null hypotheses of the model (normality, independence, and homoscedasticity), Pearson correlations analysis was conducted. This test revealed significant and positive correlations between the dependent variable (Open Access) and independent variables "transparency", "reputation", "participation" and "funding (Table 3). Regarding the independent variables, it is possible to appreciate the relationship between some of them. However, the significant correlation found was lower than 0.8 to provoke problems of multicollinearity in this model [100].

According to the analysis, the explanatory capacity of the resulting model is 67.4 percent, which was measured using the Adjusted R^2 (Table 4). As for the proposed hypothesis, five of six were confirmed. In relation to the variable "transparency", it was statistically significant and relation with "open access" found was positive, confirming the proposed Hypothesis 1 ($\beta = 0.177$; $p<0.05$). Thus, the universities which have been making greater efforts in transparency policies over the past few years, are also carrying out the relevant actions for the opening of science. These results are in line with Funamori [24] and OECD [43] who noted that the technological advance information disclosure has increased, affecting the access to scientific publications in the same way. Moreover, to carry out the implementation of Open Science,

Table 3. Bivariate correlation for Open Access.

Variables	OA	TRA	REP	ENG	FUND	FOUND	SIZE
OA	1						
TRA	0.163*	1					
REP	0.685***	-0.204**	1				
ENG	0.161*	0.331***	-.209**	1			
FUND	0.497***	0.166*	.232**	.142	1		
FOUND	-0,6	-0.102	.110	-.138	.081	1	
SIZE	0,003	0,046	.006	.229**	-.440***	-.011	1

***p<0.01;
**p<0.05;
*p<0.1
Source: own compilation

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transparency is a crucial factor that affects accountability in research at all levels in universities [101].

Following Hypothesis 2, the positive and significant relation between "reputation" and "open access" was found, ratifying the expected relation ($\beta = 0.687$; $p<0.01$). Those universities, leading the ARWU, are the most likely to follow Open Access policies. This is in line with Dijkmans, Kerkhof, and Beukeboom [102] who find that reputation is positively related to the online activities of organizations. However, in the university sector, the results are contrary to those obtained by Flórez et al [72], who indicates that reputation does not imply a greater degree in the dissemination of information.

The influence of "participation" was significant and positive, supporting the proposed Hypothesis 3 ($\beta = 0.154$; $p<0.02$). This could indicate that the universities achieving the highest levels of participation by stakeholders in social media are the ones that employ the policies with the major requirements regarding the dissemination of scientific results. This outcome can be explained by the appearance of the new indicators (Altmetrics) in the analysis of scientific activity through social media [83]. In the same line, Lampert et al [103] and Serrano et al

Table 4. Regression results.

Hypothesis	Model	Unstandardized Coefficients		Standardized Coefficients	t
		B	Std. Error	Beta	
H1	**TRA**	1,226	0,512	0,177	2.393**
H2	**REP**	0,096	0,011	0,687	9.120***
H3	**ENG**	1,063	0,54	0,154	1.970**
H4	**FUND**	4,45	1,102	0,344	4.038***
H5	**FOUND**	-0,857	0,478	-0,124	-1.793*
H6	**SIZE**	0,746	0,564	0,108	1,323
			R	R Square	Adjusted R Square
			83.80%	**70.20%**	**67.40%**

***p<0.01;
**p<0.05;
*p<0.1
Source: own compilation

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[104] note that Altmetrics have a potential impact on social engagement in access to scientific information of general interest. In addition, collaboration with citizens also stimulates Open Access, since to achieve greater engagement scientists must give access to the results of research projects to comply with the principles of fair data [105].

Regarding "funding", it turns to be a significant factor for the model ($\beta = 0.344$; $p<0.01$), thus accepting Hypothesis 4. The positive relationship shows that private universities, contrary to what is established in the literature [31, 85] are the ones that most carefully apply the recommendations made by different authorities regarding open access to scientific publications. In turn, the effect found on private funding coincides with the conclusions drawn by Saraite-Sariene et al [97], who find the positive relationship between private funding and information disclosure in the university sector. This may be because private universities, depending on students' funds, tend to worry more about their reputation, increasing their responsibility for access to all types of information: institutional, academic, research, and in this way strengthen links with their stakeholders.

With respect to "foundation", significant statistical results were found, confirming Hypothesis 5 ($\beta = -0.124$; $p<0.1$). This negative effect is in line with previous research in high education [74] and the corporative sector [106]. In the same vein, these findings support Gallego-Álvarez et al [89], who point out that research groups belonging to the older universities have had more time to consolidate and grow with the consequent need to disseminate more information for different needs.

The results did not support Hypothesis 6 ($\beta = 0.108$; $p>0.1$), thus size does not imply that universities are more prone to Open Science policies. These findings are contrary to the literature on information disclosure [90, 99, 107], where most coincide with the positive effect of size in the dissemination of information in general.

Conclusions

In recent years, Open Government initiatives have evolved along with ICTs, from the web to social media and digital platforms, which serve for transparency, participation, openness, and collaboration between an organization and its stakeholders. Accordingly, it is necessary to create communities (scientific, governments, private organizations) to improve collaboration both externally and internally of the organization based on technological innovations [108, 109]. The creation of collaboration for open organizations as well as open processes can be carried out through sharing of information, ideas, data, and other resources through digitization with the whole society including, governments, academics, private organizations, and citizens [10, 108]. On this way, Open Access has become one of the main concepts, which is settling on the foundations of Open Science [23].

At this point, different policies have been developed, different pilot projects have been started and various competent authorities [43, 66, 110] have agreed on the requirements of Open Access.

Even so, this study shows that, despite different established policies, until now the level of Open Access policies implementation remains at medium levels in general terms. Likewise, it has been verified the lack of information about many of the elements of the Open Access initiative, as is the case of mandatory compliance, deposit deadlines, or embargo period.

Furthermore, some of the universities are at the beginning stage in the implementation of the recommendations on these open initiatives. Therefore, they do not have managers dedicated to Open Access issues and do not comply with all of the aspects recommended in the official guidelines. Besides, little proactivity is observed in the dissemination of the research data.

Regarding the explanatory analysis and according to Stakeholders, Dialogic Communication and Legitimacy theories five factors should be considered as determinants of the level of Open Access policies followed by universities as part of Open Government strategies: "web transparency", "reputation", "social participation", "funding" and "foundation".

The level of transparency leads to greater use of digital platforms (for example, Open Access Institutional Repositories) for better openness of research outcomes. This can indicate that the universities which have adapted their web pages to the requirements of access to information have continued along the same lines, advancing and developing institutional repositories, taking into account the requirements and/or recommendations for the transparency of publications.

Likewise, the reputation of the university seems to influence the better adoption of Open Access policies in universities. This may be because the rankings take into account the main indexes of citations, and for a greater impact of the publications greater openness is necessary.

Active communication strategies via social media go in the same direction with Open Access policies. Taking into account the emergence of the new indicators of scientific evaluation through new ICT's and citizen collaboration in research, scientists tend to use these channels of communication to achieve a greater commitment from society. Moreover, as an accountable response to this, they also tend to share their publications more.

In addition, funding has been a notable driver in the adoption of Open Access policies in universities, with the private universities being those that make the greatest effort regarding the dissemination of their scientific publications. Hence, universities' behavior is strongly oriented toward meeting the expectations of their funders, including the need to respond to the demand for scientific openness. This helps justifying the funds invested for greater accountability and transparency in research.

Finally, the foundation also influences the best compliance of Open Access policies. These results are in line with the previous literature indicating that most consolidated universities tend to meet the expectations of information demand from their different stakeholders. This is due in part to the fact that the oldest organizations, in order to maintain their competitive advantages, have to adapt their structures and policies to the new technological and social demands.

This study seeks to contribute to both the existing literature and those responsible to manage Open Access policies in the high education field. Therefore, from an academic perspective, the findings aim to provide an overview of Open Science policies in the university sector. Specifically, to expand the scarce literature regarding the level of Open Access policies implementation and its interaction with other dimensions of Open Government initiatives. So, the present paper advance in identifying trends and gaps that should be improved upon for the Open Access policies extension. In addition, it can also provide fresh insights about the influencing factors that can lead to greater use of universities ITC's as the channels for improving information access, fostering participation, and facilitating access to scientific information for their different stakeholders.

Further, from a practical point of view, the analysis conducted on the level of Open Access in the best-rated universities could serve for other universities as the benchmark practice. This could help to reduce barriers for access to publications and identify the factors that could influence the best adoption of such policies. Knowing the trends in Open Science policies allows improving and/or developing a more efficient implementation program to advance in knowledge. In addition, universities in general, should not delay in adopting the initiatives of Open Science, since it is the best way to deal with legitimacy and accountability with science and with society. Moreover, they should make progress in these policies not only in relation to the dissemination of scientific results but also in the opening of scientific data.

Although this study presents valuable findings, it is not without its limitations, which provides directions for further research. In this regard, the sample size due to the lack of data has been moderately sized. Hence, future research could expand the sample. In addition, the directory for estimating the percentage of Open Access policies does not provide data for all universities. In this sense, once progress is made in the pilot projects of Open Science policies, an analysis of the content could be carried out to prepare an index following the recommendations proposed by different authorities. This analysis should necessarily take into account both the Open Access to the results and the dissemination of the rest of the information of the science cycle, in order to cover the concept of Open Science in its entirety.

As for the explanatory factors, these have been limited and generalized. It would be interesting to expand both internal and external, and in particular, more specific to the higher education sector and top-dawn factors related to the policies in the field of Open Science.

Finally, it has been possible to see the relationship between the three fundamental pillars of Open Government. Therefore, this study could be useful as a basis for future fruitful research on the interrelationships of web transparency, stakeholders 'engagement, and Open Science in universities. So that, it considers different contexts, by country, by the nature of the funds or see the evolution in the adoption of Open Government.

Supporting information

S1 Table. Open Access index and achieved the Open Access Policy level.
(DOCX)

S2 Table. Open Access ranking and Arwu positions.
(DOCX)

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