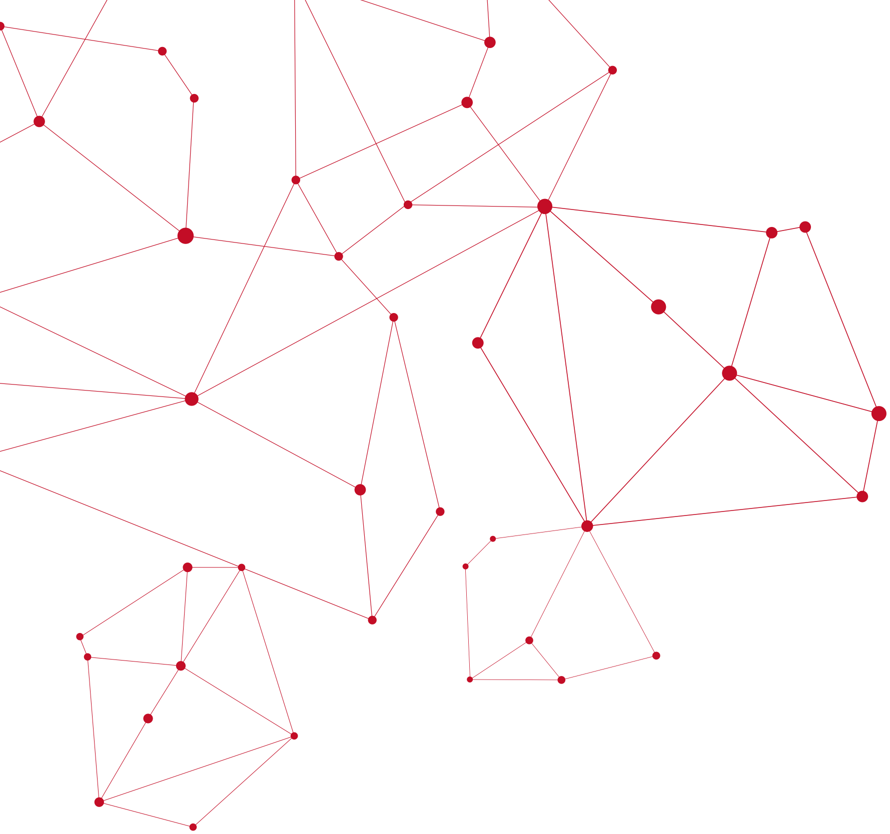
Open Science

The Challenge for Universities

INTERNATIONAL ASSOCIATION OF UNIVERSITIES

INTERNATIONAL UNIVERSITIES BUREAU



The **IAU Open Science Expert Group** brings together representatives from all regions of the world (***see members p. 35***). The report ***Open Science: The Challenge for Universities*** is the first deliverable of the Expert Group, providing an introduction to *Open Science* and outlining the associated challenges and opportunities for universities. It urges the higher education community to collaborate in shaping the adoption of Open Science principles, recognizing universities as essential contributors to the scientific ecosystem. The *report* aims to raise awareness among higher education leaders about *Open Science* and the institutional transformation it requires. Additionally, it informs policymakers and other stakeholders of the critical issues universities encounter in this transition.

Table of Contents

1. Introduction

Universities have endured over time as centres of knowledge, adapting to significant changes in their environments. They often share the ambition of being both flexible and reflective, and at the same time remaining committed to the fundamental values of higher education and to a core mission, namely fostering critical thinking, creativity, social progress, social responsibility, inclusivity, diversity and upholding the role of arbitrators of truth through academic integrity in knowledge production respectful of various epistemological traditions.

In line with the mission of the IAU, the notion of a university encompasses the diversity of the higher education institutions globally. Some are focusing mainly on research and global academic exchange, while other are more dedicated to education and higher vocational training and serving their local communities. They span the classical medieval disciplines, social science, natural science, technology, art and humanities and some incorporate learning in close collaboration with practice oriented knowledge systems —but they are all part of that community of universities, if they endorse the fundamental values of the academy.

Today, universities are facing numerous pressures spanning from political interferences, digital transformation, environmental challenges, funding cuts, decolonization processes, to repercussions of the increasing commodification of higher education. The latter often prioritizes financial gains while exacerbating social inequalities, ultimately eroding the core mission of higher education.

The question raised here is whether universities globally are willing to truly seize the Open Science movement as a transformative opportunity for higher education to collectively address current inequities and collaborate around a shared set of principles to make knowledge a global common good.

The call for open practices is equally broad encompassing data, outputs, and interactions of all parts of the research, learning and collaborative ecosystem that bring knowledge to test and fruition.

This document does not pretend that this road will be simple or straightforward - particularly in a context in which international research collaboration and openness is hampered by current geopolitical tensions generating new forms of barriers under the veil of national security. Yet, universities play a critical role in building citizens' capacity for critical and innovative thinking, fostering participatory democracies, and contributing to solutions to global challenges, as outlined in the UN Sustainable Development Goals (SDGs). For this, unrestricted knowledge circulation and access to data are essential.

The digital developments of recent decades have created opportunities for a new era of open science, influencing the way that science is done, used and embedded in society (with the word science being inclusive of all disciplines). The *UNESCO Recommendation for Open Science (2021)* provided a general framework of definitions and shared values at a global scale, along with complementary reports and toolkits to foster a change in scientific practices. However, there is scarce literature and experience on the role of universities, at an institutional scale, even though they are critical actors in this process.

Universities create a social resource by creating new knowledge, re-assessing knowledge from the past, and seeking ways of applying knowledge to human concerns, critically coupled with the education of the rising generation.

If a new era of open science is to become an effective reality and to open new doors of possibility, universities must rise to the challenge and embed new approaches to open science within their structures and priorities. But it is also important to be clear about the contemporary pressures and constraints that influence the universities and how these intertwine with open science.

This report informs universities about the key issues and opportunities at stake for universities to embark and navigate in this transformation and proposes recommendations as for why and how universities can play a leadership role in supporting and shaping a new era of open science.

The last 30 years have seen a technological revolution in the ways that information and ideas are communicated in the shift from predominantly analogue to digital processes. The consequences of this revolution have been threefold: an enormous growth in the flux of data, information and ideas; the removal of all physical and most political barriers of access to this flux; and the enablement of powerful data-based and artificial intelligence technologies that depend on such massive data fluxes for their operations. These opportunities have been seized on by the scientific community (e.g. Royal Society, 2012; National Academy of Science, 2018; UNESCO 2021) as the basis for a new era of open science[1], as a means of making scientific research and the record of science accessible to all, and making the processes of knowledge production scrutinisable, inclusive, equitable and sustainable.

The UNESCO Recommendation for Open Science (2021), adopted by the UNESCO Members States, provided a general framework of definition and shared values at a global scale, along with supplementary reports and toolkits to foster a change in scientific practices in national science systems[2]. However, there is scarce literature and reflections on the role played by the universities, at an institutional scale, even though they are critical actors in this process.

Universities are the principal employers of publicly funded scientists and the principal institutions by which new knowledge is created. A new era of open science would be unachievable without their deep engagement. The purpose of the current report is therefore to explore how open science is relevant to the social role of universities, what its benefits might be, how they could be maximised, the challenges likely to arise in achieving them and the policies required to capture the benefits, while addressing current asymmetries in knowledge production and ensuring equitable contributions across disciplines and countries.

We must however be aware that the crests of novel technologies are usually heralded by optimisms that are rarely borne out in practice (Acemoglu and Johnson, 2023). The WorldWideWeb was presumed by its inventor to offer the liberating possibilities of a “global town square”. Instead, in addition to its benefits, we have solutions to the advertiser’s dream, a means of efficiently targeting consumers, and the most powerful engine of lies that the world has known. It has been argued for example (Tyfield, 2013)

[1] Open science is not new. The first phase of truly open science occurred in the 17th century with the advent of the first scientific journals. This connected distant minds and enabled an intellectual chain reaction that inspired the scientific revolutions of succeeding centuries, though global connectivity was impeded by physical and cultural barriers. It is for this reason that we refer to a new era of open science, enabled by new communications technologies, to distinguish it from an earlier era of open science.

[2] See the toolkit Series: Checklist for universities on implementing the UNESCO Recommendation on Open Science; https://unesdoc.unesco.org/ark:/48223/pf0000383328?posInSet=11&queryId=4b667d88-e08b-428b-bfe0-b8fcb7a73124

that the release of vast troves of data, papers or research results, although potentially beneficial to science, simply exacerbates the trend towards increasing marketization and corporatization that disproportionately benefits large corporations and opens the door to a capture of publicly funded research value by commercial platforms. Science could be bureaucratised, replacing creative serendipity by ordered collaborative structures driven by yet more 'metrics' of productivity to 'incentivize' scholars to work harder and focus on the system-wide progress of science as perceived by citizens at large.

BOX 1: THE WORDS "SCIENCE" AND "SCIENTIFIC"

A particular problem in the English language is the absence of a word that describes, as a collectivity, all the disciplines in a university, even though, as we argue in the section below, all work to the same intellectual template. Some restrict the word science only to natural science. Others refer to natural science, social science, medical science and engineering science, but balk when they come to the humanities. The German language, for example, does not suffer this problem, where "Wissenschaft" covers all bases. Some members of our group prefer the term "research" as embracing the whole collective, but this refers only to one aspect of science, and not all research is conducted in a way that belongs within Wissenschaft. "Scholastic" and "scholarly" are adjectives, not nouns, although "scholastic research" might fit the bill, but some dislike the elite connotation that this might carry. We have therefore opted to use the word "science" to cover all the disciplines to be found in a university (the equivalent of Wissenschaft). We follow, in this approach, in the footsteps of UNESCO, which regards Open Science as covering all the disciplines, including the humanities.

2. UNIVERSITY ROLES AND SCIENCE FUNDAMENTALS

2.1 Challenges to universities

Universities explore the most theoretical and intractable uncertainties of knowledge and yet seek the practical application of discovery. They test, reinvigorate and carry forward the inherited knowledge of earlier generations which they teach to successive generations of students. In assessing the role that open science might play in universities it is important to understand the way they currently discharge their social role (Boulton and Lucas, 2008). The potential value to society of a university is built on interactions between teaching and research. The primary output of a university comprises evidence-based knowledge and the people who embody it. There is no evidence that the best researchers are also the best educators, indeed it seems that highly cited researchers are most likely to be classified as poor teachers (Buchanan, 2018). It is a finding that undermines the implicit assumption of many universities, that the best researchers are the best teachers, which justifies the preference that is almost invariably given to research in the university appointments process.

This is potentially a serious failing in many universities' appointments strategies. It is the interaction between the research and teaching processes in an environment of rational and respectful debate that creates the potential of the university.

The output of research is new knowledge whilst education helps to form new people. The two are coupled: new knowledge supports education, and better educated students enhance the creation of knowledge. New knowledge comes from university researchers and from the many other knowledge creators, whose combined contributions create a global knowledge stream, primarily through the medium of publication. Ready access to the global stream of knowledge is essential for all, both researchers and students, and even for the strongest research teams this knowledge stream far outweighs their individual contributions to it. The skills of university research teams give them the potential to explore how this existing knowledge can be best used in education and innovation in the local or national settings in which they work, in addition to inspiring them, in turn, to new scientific insights.

These attributes form the basis of the university's diverse capacities and their specific social role, whether this be internationally focussed and research intensive, locally focussed with strong outreach, strongly educationally focussed, or with particular focus on technology and industry links or disciplinary areas such as the humanities, engineering or medicine, or any combination of these. Whereas there are many different species of university, all those worthy of the name belong to one genus: a place where the boundaries of what is known and understood are probed to the benefit of students and of society as a public good.

Here, however, lies a serious impediment to the efficient operation of the global knowledge stream, in the extraordinary way that scientific results are published, a crucial issue for open science that is discussed further in section 6. Rather than having peer-reviewed results freely accessible to all on the web, giving easy access to the global knowledge stream for both readers and authors, a large proportion of highly cited journals have a high price tag. These restrict access to them by paywalls set to extract maximum levels of funding from the rich science systems of the global north, where GDP per head is typically 10-100 times greater than in low-and-middle income countries (World Bank, 2024), thereby limiting access by authors or readers or both in those countries. It makes certain researchers' achievements invisible on the global stage, inhibits their access to the research outputs and fractures the international science community. Excessive prices to access and to publish are depriving institutions of access to current knowledge, and for contributing to the global knowledge stream, thereby depriving the international community of potentially valuable insights. The public good of science, where the value of knowledge increases as the number of people possessing it increases (Stiglitz,1999, Willbanks, 2006), is lost through premature commercial appropriation for the private benefit of small numbers of shareholders. It is a process in urgent need of reform.

2.2 The nature of science

Science creates knowledge as a community effort. At its best, that community is global. The sharing of practice increases the accuracy and reduces the uncertainties of its findings. Science is ideally self-correcting through sceptical review, independent reproduction or replication[3] and statistical validation. It has proved to be the most reliable way of acquiring knowledge. Its processes help us to differentiate between misinformation and legitimate, evidence-based knowledge (Alberts, 2024). Ensuring the trustworthiness of science requires constant vigilance by scientists and their institutions, particularly universities.

It is important to understand the epistemological frames (gateway) within which universities work and how open science approaches might influence this. In the enthusiasm for open science, it is important that we are clear about the essentials of science, not its semantics (Box 1) but the reality of its practice. In recent years, some of the easy assumptions about the sources and legitimacy of knowledge have been questioned by a resurgence of demands for attention and relevance to modern needs from indigenous communities that retain collective ancestral ties to the lands and natural resources where they live or from which they have been displaced. In a world of competing belief systems that do not necessarily depend upon empirical knowledge, and different routes to the creation of empirical knowledge, it is important to set out with clarity what we understand science to be.

Science is concerned with the same phenomena that have taxed the human imagination from early times but expressed and assessed in ways that make it a special form of knowledge. The pathways of claims to new scientific knowledge are many and various: rational or empirical, experimental or observational, and most, possibly all attempts to describe these pathways in a few sentences failing because of the difficulty of covering all the pathways to new knowledge. Ultimately however, all these routes must satisfy scientific essentials, the refusal to accept anything without testing and trial, the capacity to change previous conclusions in the face of new evidence and the reliance on observed fact and not pre-conceived theory. This process of testing conclusions, to destruction or otherwise, is crucial in making science self-correcting and in delimiting the bounds of science, where the gatekeepers are requirements that: Novel knowledge claims and the evidence on which they may be based are made widely available and formally tested against reality and logic through processes of sustained and organised scrutiny by peers.

These are regarded by the International Science Council “as the norms of a specific scientific ethic” (Boulton, 2021). They are applicable to all the studies undertaken in a university, whether in physics, medicine, history or literary criticism, which justifies describing all as science, as set out in [Box 1]. Knowledge claims must be accompanied by the arguments and evidence on which they are based, and both must be made openly accessible for scrutiny by peers. Definitions that fail to capture these essentials, and most do, fall flat. Science is a way of working, a process not an outcome, it is more of a verb than a noun. It is a route by which error is identified and rejected, rather than truth established.

[3] Reproduction refers to the recreation of a result using the same methods and data as the original. Replication refers to recreation of a result using a different approach.

Scientific reasoning is not, as is sometimes supposed, remote from normal human reasoning, but an extension of it. It is not, in essence, an elite enterprise but part of the fabric of society. Scientific knowledge is essential for human and societal development at all levels. We acquire understanding through observation of patterns in nature and society as a basis for general rules that are progressively amended as we find exceptions to the rule. Scientific reasoning is not different. Not even parallel. It is merely a rigorous extension of such reasoning with the addition that truth claims are sceptically tested against reality and logic by the scrutiny of peers in an attempt to identify error. By opening up the access to science, universities provides transparency as a measure to develop and uphold the trust needed since every argument and finding cannot be tested all the time.

3. CONTEMPORARY CHALLENGES TO UNIVERSITIES

3.1 Trustworthiness and Trust

The trustworthiness of science lies in the integrity of its processes, as alluded to in section 2b. There is ample evidence not only of practices that ensure integrity through open exposure of working methods to sceptical review, but also growing and widespread evidence of sloppiness, malpractice and even fraud as discussed in section 6.

Trustworthiness, though vital, does not necessarily lead to trust. Populist actions to discredit inconvenient scientific research and institutions have been enabled, in part, through the creation of silos of like-minded people on social media platforms, to promote powerful "alternative facts" (Aaron, 2017). Populists have been successful in mobilizing substantial constituencies by linking climate change denial to a wider attack on (urban) elites and the political establishment, grounded in anxieties about the pace and cost of social and economic change, migration and the loss of national sovereignty. Misinformation and disinformation, increasingly powered by AI, are identified as the most severe global risks over the next two years in the latest Global Risk Report of the World Economic Forum (2024) "undermining social cohesion, trust in institutions and fuelling political divides" (UNEP, 2024). These issues are being confronted by many representative bodies of science, but they are also issues with which the universities, as the principal storehouses, sources and disseminators of their societies' knowledge should be intimately engaged.

3.2 Respecting diversity

A vital priority for a new era of Open Science is that universities must recognise, respect and benefit from the global diversity of cultures, practices and priorities that they encompass internationally. Otherwise, open science risks being seen simply as an extension of a western dominated system, whose values are represented by the competitive ranking systems (see section 6) that validate predominantly Western priorities and ways of working and undervalue output, priorities and epistemologies from other regions, particularly those of the "global south", but also to the knowledge developed through our practices, vocations and art.

It is important for university leaders to consider the mechanisms through which this priority might be pursued as a natural extension of the internationalisation agenda of recent years, through novel forms of exchange, mutual support, and collaboration, where colonial attitudes are set aside and there is a priority for mutual learning and not for tutelary relationships.

3.3 Access to the global knowledge stream

Access to what we have called the "global knowledge stream" is both a profound asset to the research and teaching of a university and a means whereby a university's own research can contribute to the wealth of human understanding. As commented in Section 3, much of this stream is owned by commercial publishers who either require payment to release it to universities or allow free access by readers (open access publications) but transfer this payment to authors. Irrespective of the mode of payment, it is a system that penalises poorer institutions and low- and-middle income countries and, as noted before and inhibits the inclusive diversity referred to in section 3b.

3.4 Risks of modern university

Many university systems experience financial pressures, the consequences of which are frequently to squeeze diversity by concentrating on the most lucrative activities and withdrawing from experimental activities that could hold future benefit (Michell, 2022; O'Hara, 2024). As many higher education systems are heavily reliant on government funding, partial government control or government ownership, focused on activities in teaching and research that support national economies and governmental outlooks.

For universities, which tend to be subversive of authority, at least in the student body, this can pose severe problems of public diplomacy. In such a setting, the temptation is to manage for financial success rather than for the broader horizons set out in Section 2.

These stresses occur in the context of revolutionary changes. The digital revolution and developments in AI have together offers new tools and opportunities that can be explored by humans in transformative ways. Progressively it penetrates new domains, boosting productivity across all sectors and industries because of new opportunities, but often driven by cost effectiveness. It is globally pervasive, raising questions regarding pre-existing norms and unleashing an unprecedented new era of innovation that has profound implications for society. Whether society can exploit these changes to its benefit, or whether it will be exploited to the benefit of a few remains to be seen but it is notable that the university has been relatively untouched. Will the university absorb the potentials of this general-purpose technology and use them to develop an open science that exploits this revolution to the benefit of societies and economies? Or will the university's central functions be absorbed by the technology companies that increasingly dominate many sectors of modern life? Section 7 illustrates how technology companies could privatise swathes of knowledge by exploiting copyright to scientific articles and creating new knowledge from them through generative AI systems. Micro-credentials that offer short courses that are engineered to fit the needs of specific sectors or companies would be cheaper, less

less time-consuming and less subversive of authority than the typical courses offered by a liberal university[4].

One of the perennial dilemmas for a university funded by governments is how to exploit the full potentials of the university. They to tend to be funded to respond to extrinsic objectives such as producing "highly ranked research", "graduates in topics that are deemed productive in national economies", and "output that will fuel the engine of commercial innovation", rather than to stimulate the cultures and perspectives of their region and to debate and promote local and global issues except through the papers that they publish. These hopes from national or private funding can come with restrains and steering that privatize or nationalise findings – for the sake of short-term competitiveness. Geopolitical tensions add to these concerns – and all are threats to the long-term goal of open science. The essential creativity of the university emerges from the tension between the dynamic process of engagement in the pursuit and explanation of knowledge and sensitivity to the needs of the contemporary world and the problems that preoccupy it. Releasing their broader potentials in world of fixed budgets and strict accountability demands a combination of steady nerve and opportunistic flexibility. In the modern setting, easily managed university is hardly worthy of the title.

4. OPEN SCIENCE AND THE UNIVERSITY

In a world where data and information have become driving forces of an immensely powerful general-purpose technology, and where private interests could come to control key parts of the scientific enterprise, universities are vital in ensuring open science and public ownership of and access to knowledge.

The current, monetizable priorities for data science and artificial intelligence are in surveillance, warfare, automation and proprietary data platforms (Acemoglu and Johnson, 2024). Such choices tend to be driven by narrow economic priorities, rather than by social consensus. Universities, in maintaining an open science perspective could be influential in developing such a consensus through their influence on the outlook, interests and skills of talented graduates that will work in technology sectors, policy making and government, and by wider open science engagement in the public domain (figure 1). Of course, questioning the interests of the powerful can elicit strong or forceful reactions, against which the concept of academic freedom is a necessary bulwark. Although many universities have developed significant priorities in open science[5]. It is important that there is a global forum – such as the International Association of Universities - to lead these conversations and provide recommendations on behalf of universities.

If the voice of the universities were to become more resonant in the development of open science, where should it be directed? The UNESCO recommendations regard open science as a means of ensuring that the practice of science and scholarship is compatible with the broadly desirable attributes of making science more accessible, inclusive and equitable, in addition to improving the efficiency of science. UNESCO's position is that: "open science is not an end in itself, but a means towards fairer, more equitable,

[4] By this we mean a university with a wide range of concerns that are unrestricted by governments and by the tradition of academic freedom.

[5] e.g. University of Utrecht: https://www.uu.nl/en/research/open-science; Autonomous University of Mexico – UNAN- *https://acsopenscience.org/customers/unam/* are examples among many others.

If the voice of the universities were to become more resonant in the development of open science, where should it be directed? The UNESCO recommendations regard open science as a means of ensuring that the practice of science and scholarship is compatible with the broadly desirable attributes of making science more accessible, inclusive and equitable, in addition to improving the efficiency of science. UNESCO's position is that: "open science is not an end in itself, but a means towards fairer, more equitable, diverse and inclusive research systems that are better geared towards the production, dissemination and use of scientific knowledge that helps address societal challenges with benefits for all" (UNESCO, 2024). In pursuing this perspective on open science in the aftermath of endorsements its national members, UNESCO has set up working groups on capacity building, policies and policy instruments, funding and incentives, infrastructures and monitoring (https://www.unesco.org/en/open-science). It is too early to assess the effect of these initiatives on the practice of science, and although many academics have been involved, there is little sign that the same is true of universities as institutions. The IAU is an ideal platform for universities to jointly take a stance on open science and liaise as appropriate with UNESCO for its implementation.

As UNESCO's essentials are attributes that universities already aspire to, we identify a more focussed set of practicable targets for universities that make the advantages of open science clearer and help to identify the infrastructures and projects that universities and their funders might wish to plan for. Figure 1 takes the "openness" identified by UNESCO and organises them into inner and outer orbits. Without the inner orbit of open publication, open evidence/data and openness to society, open science would be a delusion. It would fail the test of science and fail the test of openness.Without the outer orbit it would fail to exploit the full potentials of open science. It should be noted that as open science applies to the whole range of scholarly disciplines, the extent to which a discipline relies on all the infrastructural elements in the outer orbit varies considerably.

Moreover, the extent to which relevant outer orbit elements can be provided in systems where funding is weak will often be a determinant of applicability.

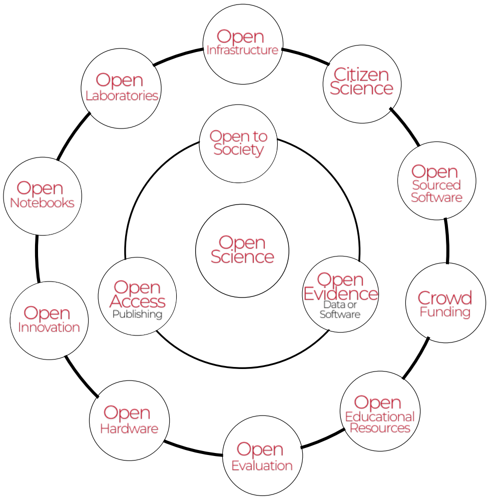


Figure 1. The constellation of open science. The inner orbit comprises open access publication, open evidence (data & relevant software), and open to society, as fundamental to a new era of open science. In contrast, the outer orbit includes a range of important open assets that are good to have rather than being absolutely necessary.

We then identify four practical and crucial priorities for universities in the open science arena, all of them being relevant to the contemporary challenges set out in Section 3. They are:

1. Opening the workings of science to scrutiny, both to peers and to the public, as powerful means of ensuring rigour and honesty and therefore the integrity of science, its efficiency for users and its trustworthiness.
2. Open collaboration across the scientific community including the sharing of data in interoperable formats to enhance value through collaboration and efficient use of resources.
3. Openness to society in which universities extend their public engagement in the joint creation of actionable knowledge and to support the development of a "scientific temper" in society (See Section 5).
4. Building bridges across international society as parts of an international scientific and scholarly community that is aware of regionally and culturally varied contributions to the tapestry of human knowledge.

The questions for universities are whether they are prepared to take up these four major open science challenges and the responsibilities that they entail. The question for national governments, all of which have endorsed the UNESCO recommendations on open science, is whether they will enlarge the scope of their funding so that universities are enabled to take up these challenges. by UNESCO and organises them into inner and outer orbits. Without the inner orbit of open publication, open evidence/data and openness to society,

5. OPEN SCIENCE PRIORITIES FOR UNIVERSITIES

5.1 The integrity of science

Maintaining the integrity of publicly funded research, most of which is done within universities, is an essential responsibility of universities (Barber, 2021). It is a responsibility that is best discharged through open processes. The integrity of published science is currently threatened by the overproduction of papers of little if any value and the rise of predatory journals. It is driven by a "publish or perish" ethos that incentivises academics and universities to publish research irrespective of its quality in ways described in Section 6. It is vital that academics and their universities maintain or develop open processes of research and publication that ensure high levels of integrity. The relatively weak integrity of much scientific research is particularly damaging in the current context where science and its institutions are widely denigrated.

Openness is the key to ensuring integrity. The processes of science must be efficiently scrutinised by peers to ensure that error is identified, arguments can be discussed and uncertainly minimised. Independent, open scrutiny of observation, experiment, analysis and publication minimise avoidable errors and underpin the self-correcting character of science. That such integrity is failing has been revealed by recent attempts to systematically replicate the results of series of otherwise highly regarded published papers

papers in, for example pre-clinical oncology (sample of 53 papers-Begley and Ellis, 2012), social psychology (100 papers-Kleinberg et al, 2015) and economics (67 papers - Chang and Li, 2015). They were successful in only 11 %, 39% and 33% of cases respectively. The reasons deduced for these failures included falsification of data, invalid statistical reasoning and absent or incompleteness of the data or metadata. Taken together with publications that seek merely to meet production targets, such outcomes threaten the credibility of the scientific endeavour unless corrective action is taken. If data, meta-data and the code used in any manipulations are not available for scrutiny, published work, whether right or wrong, cannot be subject to scientifically indispensable testing by reproduction or replication. This underlines the vital need to expose all necessary information for scrutiny and the responsibility of authors and their institutions to do so, except where confidentiality, safety or security are at risk, in which case special steps should be taken to permit proper scrutiny (Royal Society, 2012).

A poll in 2016 (Baker, 2016) showed that more than half the scientists polled believed that science was facing a replication crisis, potentially sufficient to undermine public confidence in scientific results and reflected in widespread failure to reproduce the results of published science in large scale replication projects such as those in the previous paragraph. It is a situation that requires a response from all scientists, particularly as it has been demonstrated that greater attention to rigorous and open processes such the pre-registration, large sample sizes, attempts at self-replication, data sharing and careful, open descriptions of method (See 6.3) can dramatically improve reproduction rates (Protzko et al, 2024).

Open processes have the capacity to increase the integrity and cost effectiveness of the scientific process and should be required by universities and adopted as norms of science in the training of academics, other researchers and indeed of undergraduate students. They involve enhancing procedural rigour in problem formulation, observation, experiment and analysis, by exposing these processes to open scrutiny and testing that increasingly involves massive data handling and AI methods. Such processes vary greatly with the nature of the evidence, which tends to vary with the discipline. The evidence may be descriptive or experimental, it may be quantitative or qualitative, and an increasing range is data-intensive. A number of schemes have been developed to maintain high levels of integrity according to the nature of the evidence. Data-intensive research, which has very demanding requirements for integrity is increasingly extending beyond its traditional fields of the natural sciences, engineering and medicine, into the social sciences and digital humanities (Drucker, 2021). The disciplinary difference not only connects with integrity, but also with the interculturality of science and multilingualism.

An example of a scheme for integrity is that of the Center for Open Science at Charlottesville, Virginia, USA (https://www.cos.io/). This was founded in 2013 to develop open research practices, democratise research, enhance research integrity, expand sharing, improve reproducibility and thereby strengthen self-correction. A Transparency and Openness Promotion (TOP) Committee has proposed guidelines for essential processes to improve integrity (https://www.cos.io/initiatives/top-guidelines) as in Box 2.

BOX 2: A CHECK-LIST FOR MAINTAINING SCIENTIFIC INTEGRITY

Publication Standard: Articles should not be published until they comply fully with data citation guidelines (e.g. FAIR: findable, accessible, interoperable, reuseable - Wilkinson et al, 2016).

Data Transparency: Requirement to post data to trusted repositories before publication.

Analytic Methods Transparency: Mandatory independent reproduction of analyses from code posted in trusted repositories.

Research Materials Transparency: Detailed disclosure of research materials, moving towards independent verification.

Design and Analysis Transparency: From encouraging transparency to mandating transparency standards which must be enforced rigorously.

Study and Analysis Plan Preregistration: Detailing whether studies and analysis plans were preregistered, moving to preregistration and verification as prerequisites for review and publication.

Replication: Encourages the submission of replication studies, progressing to more stringent measures such as results-blind review to ensure integrity and reliability of replication efforts.

The content of each of these elements will depend on the discipline in which they are applied and on the nature of the evidence. Adopting such an approach for the release and dissemination of scientific concepts should become the norm for scientists and their institutions, in part to adapt to the new rigours that are required to deal with abundant digital data, in part to respond to the need to ensure that the enormous contemporary increase in scientific claims can be efficiently navigated without having to waste effort on dealing with inadequately presented conclusions. Nosek (2019) has argued that dealing with these issues does not merely require a change in ways of working, but a change in culture for many. Changing a culture of working is easier said than done however, but Nosek has helpfully suggested a sequence of steps that would favour such a change, as shown in Box 3.

BOX 3: A CHECK-LIST FOR CULTURE CHANGE

1. Make it possible. Having a worked-through scheme, such as the one described above, that is appropriate to the relevant discipline and the nature of the evidence.

2. Make it easy. Providing expert technical and infrastructural support and adapting the norms of publication to new requirements to ensure that it is easy for authors to comply.

3. Make it normal. It is important that processes that uphold a high level of integrity, such as those described above, are widely regarded as essential to science, by scientists, universities, learned societies, unions, associations, academies and funders.

associations, academies and funders.

4. Make it rewarding. Procedures that assess the importance of scientific contributions must reward the integrity of process and should NOT simply be an assessment of prowess in publication.

5. Make it required. Funders should require that such processes are an integral part of proposed research while reports on the research should demonstrate implementation. Scientific publishers should require evidence of compliance with these norms as a condition of publication. Universities should develop processes that encourage these requirements to be observed.

It is often assumed that fraud is rare and does not cause lasting damage because "science is self-correcting". It is becoming clear, however, that this rosy picture may be mistaken. First, there have been several high-profile cases of eminent researchers whose work has been found to be fraudulent. Second, there has been growth of "paper mills", sometimes colluding with corrupt editors to place articles. The seriousness of the threat from paper mills became evident in 2023 when the publisher Hindawi, a subdivision of Wiley, retracted over 8,000 articles, with ABC News commented that this was "just the latest in a broader crisis of trust that universities must address" (ABC News, 2024).

Most sources of information about fraud are scattered and are not in peer-reviewed papers.

As an example, Paolo Macchiarini published fraudulent claims that an experimental stem cell treatment was successful, leading to direct harm to patients. It took five years before he was convicted and fraudulent papers were retracted. Meanwhile, criticisms of Macchiarini's collaborators have been ignored. There is little agreement about whose responsibility it is to investigate accusations of fraud and what sanctions should be applied when fraud is proven. No organisation has appropriate investigatory or regulatory powers. In general, dealing with fraud is left to universities, who may lack expertise, particularly when dealing with new developments such as paper mills or use of AI to generate fraudulent papers, who are likely to have conflict of interest, and who may be reluctant to apply sanctions, even when fraud is clearcut, because of concerns about litigation (Bishop, 2024). It is increasingly an area of science where governance responsibility is needed.

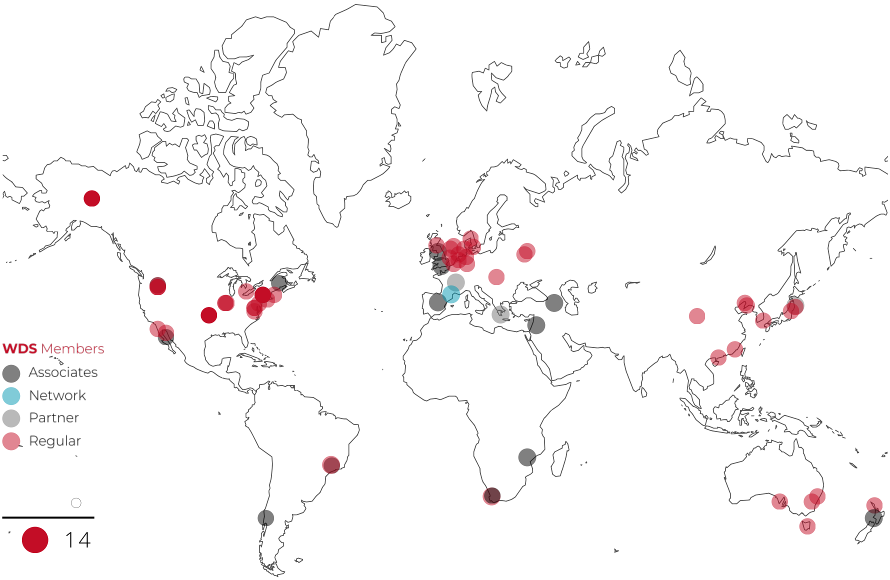
5.2 Open collaboration within the scientific community

In the later decades of the 20th century, the hegemony of disciplinary science, each with its own internal hierarchies, driven by the autonomy of scientists and their host institutions, evolved in part towards a developing paradigm of knowledge production which is socially distributed, application-oriented, trans-disciplinary (in the sense of involving interaction with citizens) and subject to multiple accountabilities (Novotny et al, 2003). This coincided with science being increasingly confronted with

Taken together, these trends have increased the desirability for greater data sharing and coordination of effort in larger teams. This pressure for greater collaboration and sharing has in principle increased the efficiency and creativity of the scientific enterprise. Valuable data is increasingly shared by separate teams, and an increased diversity of perspectives have been applied to problems. At some national levels, well-managed, shared data resources, shared equipment and archival infrastructures have been created or are being planned or discussed (e.g. https://gphandlahdpffmccakmbngmbjnjiiahp/https://dam.ukdataservice.ac.uk/media/622417/managingsharing.pdf). Such resources and such settings are also important in determining access to learning opportunities and career advancement for young researchers. These open science developments within the scientific community draw attention to the disparity of opportunity between the science systems of the different countries of the world. The IAU could provide an important locus for discussions about mutual support between less well-endowed university systems for collaborating infrastructures.

The barriers to such collaboration are the cultural challenge of accepting that extensive collaboration is a norm, and that effective collaboration depends upon integrity within collaborating groups and the availability of infrastructures. Collaboration between different groups within the same discipline can ensure that maximum benefit is obtained from hard-won data resources. Equally, inter-disciplinary science is vital if the complexities of most of the systems that are of benefit or concern to humanity are to be understood and addressed. In all these cases, it is vital and onerous that the procedures of Section 5 are developed and maintained if integrity is to be achieved and data is to be usefully inter-communicated.

Figure 2. Example of the north/south contrast in data centre availability, showing the locations of World Data System facilities. (With acknowledgements to the World Data System: https://worlddatasystem.org/members/members-map/)



There is a particular problem for much inter-disciplinary science, where different, discipline-specific ways of dealing with data depend upon enhanced modes of inter-operation (Leal et al, 2019). The provision of national or international infrastructures that provide the means of collaboration are essential and are currently being assessed through UNESCO's work on open science (Pade, 2022). The first requirement is broad-band connectivity, which is well served in most of the global north, much less so in the global south. Scientific data-centre capacity is similarly unequally distributed, as shown in figure 2. This latter issue strongly influences the nature of "north-south" collaboration in data-intensive science, where the lack of global south centres tends to favour data migration to the north. During the West Africa Ebola pandemic of 2013/2014, there was much support from many countries, but at the end of the outbreak, most of the collected data was repatriated to those countries, with little available to West African centres because of a lack of relevant data repositories. This underlines the crucial importance of local data centres in the global south, where universities have a major role to play (Bosa et al, 2014).

5.3 Open to society

The modes and technologies of communication have been central to the development and reach of sciences and the universities. The development of printed texts, the creation of scientific publications and now pervasive digital technologies have all had major implications for science and universities. This latest, digital development has fuelled debate about whether a new era of open science can exploit the reach of digital technologies[6] in amplifying the impact of the social resources created by universities.

The potential social transformation that could be stimulated by science and the universities was anticipated by Jawaharlal Nehru, first prime minister of independent India, when he wrote about the role of science in society and the universities which are its custodians (Nehru, 1946). He wrote of "the search for truth and new knowledge, the refusal to accept anything without testing and trial, the capacity to change previous conclusions in the face of new evidence, the reliance on observed fact and not pre-conceived theory...that should be a way of life, a process of thinking, a method of acting and associating with our fellowmen...It is the temper" (the temperament or spirit) "of a free man." These concepts were embedded in the constitution of India, in the hope and expectation that with wise governance and healthy democratic debate, such a "temper" would come to characterise the actions of the newly liberated population. Such an aspiration is a noble one, which some believe can be identified in the slow tread of history (e.g. Pinker, 20ll) with universities as places from which it should be promoted.

An informed population infused by a sceptical scientific spirit would be a more responsive popular basis for the difficult political decisions governments need to take to confront contemporary global challenges, rather than a public sphere that is easily and sometimes unquestioningly moved by conspiracy theories and easy populist solutions (Section 3). A crucial form of engaging with citizens on these issues, and of great potential significance, is the transdisciplinary mode of science. This brings us back to our earlier point that scientific knowledge can

[6] The digital revolution has created unprecedented global connectivity. In early 2024, 5.65 billion people had a mobile phone, 5.44 billion (or 67%) used the internet, and 5.07 billion used social media, out of a total population of 8.1 billion, and with a growth rate in internet usage of 3.4% per annum (https://datareportal.com/global-digital-overview). This compares with an average internet usage of 48% in the African continent. (https://www.statista.com/forecasts/1146636/internet-users-in-africa).

rarely be applied and successfully adopted in a given social setting without taking into account the perspectives and priorities of those working in that setting. It requires deliberative engagement between knowledge partners who seek to reconcile different perspectives in defining and addressing a problem (Sen, 1999). It is as important in achieving effective action for the great contemporary global issues such as climate change as it is in local ones such as the provision of water supply for a rural community. It is an approach being taken up in many countries in the global south, particularly in Africa, where community engagement is regarded as crucial to the success of many developmental programmes (Bawa, 2014). This transdisciplinary perspective sees science as a public enterprise, not one conducted behind closed laboratory and library doors although current research assessment systems reward work published in 'high impact' journals, with little credit to the outputs of the application of transdisciplinary research (Mach et al. 2020). Such broadening of the community and regional role of the University is developing at a number of universities worldwide (e.g. Utrecht, Pretoria, a large number of institutions in Latin America, Zurich etc). Case studies of transdisciplinary work increasingly abound from both global north and south (Lawrence, 2023; Lepore et alii, 2023). The strict priorities of the global ranking systems of universities produced by publishers that prioritise a particular form of research are inimical to the above intellectual enterprise. Indeed, it may be for that reason that the universities of Utrecht and Zurich have left the global rankings.

Public engagement, including engagement through 'citizen science,' is a vital priority for modern science not only because of its effectiveness but because of the need for science to be seen as a public rather than an elite enterprise. White coats, strange laboratories, arcane language and austere and prestigious universities speak to the idea of science as an elite enterprise. At a time of populist policies and a loss of faith in democracy (Wike et al. 2020), an elite image can readily undermine trust (Greenfield 2022), and popular trust in science is crucial if we are to successfully confront many modern challenges. Public engagement is an essential part of the process of building trust. A serious problem in the public perceptions of science is the way that the words "science" and "scientific" are understood as implying certainty and truth. In reality, science is as much about uncertainty. The contrast was recognised by Voltaire, writing that "whilst uncertainty is uncomfortable, certainty is preposterous" (Voltaire Foundation 2018).

Consistent with UNESCO's recommendations (2021), this demand for a stronger presence in society requires universities to engage proactively and partner with other societal actors. Furthermore, becoming open institutions will imply transforming higher education by "fostering epistemic dialogue and integrating diverse ways of knowing".

5.4 An international open science community

The last half century has seen a massive growth in the worldwide population of universities[7]. A growth that has created a global academic community bound together by a shared commitment to evidence-based knowledge, as the pre-eminent non-religious, transnational community in the

[7] Global student numbers in higher education have grown from 51 million in 1980 to 235 million by 2023, and with an extrapolation of 590 million by 2040.

contemporary world, although one with diverse priorities. This is a timely reality when so many of the grand challenges facing humanity are simultaneously local and global. Universities can be natural bridges between local, national, regional and global science systems, with the potential to provide for the free flow of scholars and scholarship that are essential to addressing humanity's grand challenges, a crucial dimension for a new era of open science. If we are to create the internationally coherent policies that will be essential in successfully addressing these challenges, we must ensure that this diversity of experience is understood, that those that carry the heaviest burdens are compensated for this service, and that those that lack resources to adapt are supported in doing so.

It is important that universities formally recognise the crucial international dimension of open science and their role in supporting it. They have a major responsibility to promote open science as a global public good by creating and facilitating the flow of ideas and opportunities across their international networks. The academic publishing system should provide a friction-free conduit for such flow, where all parts of global academia are efficiently networked in such a way that new ideas and results are immediately accessible everywhere and by all.

A fundamental question for this transnational collectivity of universities is whether they could, or should, intervene internationally with a distinctive global university voice. Acknowledging that each university operates in its own national context, with different government policies, priorities and constraints and these national differences can make it very difficult, if not impossible, for universities to agree on a single, unified voice on global issues. Nevertheless, it could be interesting for the universities and their academics to create a global frame to express their perspectives regardless of their differences.

How should universities situate themselves in relation to the ways that different societies have constructed their knowledge about the world and ignored the different pathways to knowledge of historically marginalised communities?To what extent should they reflect it, and to what extent should they have a common, approach? It is a vital priority for a new era of open science that the "global university system" must recognise, respect and draw on the global diversity of epistemologies, cultures, languages and practices of the different social and intellectual environments in which universities work. Open science must not simply be an extension of a western dominated system, whose values are represented by the competitive ranking systems that validate predominantly western priorities and ways of working and undervalue output, priorities and epistemologies from diverse regions, particularly those of the "global south". A new era of open science must cherish and benefit from the rich and diverse global tapestry of experience and perspective. This global dimension of open science is a crucial one, in which open, global conversations, collaborations and actions are pursued by a global community that is able to bridge between national and diverse global dimensions. It is vital for university leaders to consider the mechanisms through which this might be pursued as natural extensions of the internationalisation agenda of recent years through novel forms of exchange, mutual support, and collaboration, where colonial attitudes are set aside and there is a priority for mutual learning and not for a tutelary relationship.

Nehru's comments in Section 5 set out attributes that we should seek to inculcate in all our students, whether they are engineers, political scientists or literary theorists. It is not the role of universities only to fine tune their students to the interests of a particular employer, as is assumed by many who see "micro-qualifications" as the future. That is a deeply damaging fallacy. Universities' primary role is to help form intellectually free individuals in Nehru's sense. This perspective also offers an eloquent description of the "knowledge system" inclusive of diverse epistemologies and cultures - whether that of a highly articulated modern city or of an indigenous tribe - to which all universities should aspire. This may serve as the source of collective strength of a global university network. In contrast, "belief systems" do not necessarily require evidence, although most involve a complex entanglement between belief and knowledge. Universities explore this entanglement between the empirical knowledge system and the global mosaic of epistemologies and of political, religious, philosophical and cultural belief systems.

6. SCIENCE PUBLISHING: THE NEED FOR REFORM

6.1 Publication and citation

Publishing is fundamental to the scientific endeavour and to open science. It makes up the core of the "global knowledge stream".

The publishing landscape is however complex, and in some parts highly problematic. It consists of two principal sectors, a "for-profit" and a "not-for-profit" sector. In this section we discuss the attributes of publishing in so far as they influence the priorities of open science as set out in this report.

It is important to understand the environment in which publishing operates, the way that publishers have adapted to the demands made on them by scientists and the extent to which the resultant consequences serve the needs of open science. There have been three major shifts in the environment in the last half century that have influenced the publishing landscape:

- Science publishing has evolved from a state when getting into print was the major obstacle, to the current state when almost any article can find a publisher. The major current challenge is to be read.

- Governments worldwide have recognised a fundamental shift in the basic economic resource, from capital, land, and labour, to knowledge and those in whom it is embedded (Drucker, 1993). It is a realisation that has moved universities from the margins of government concerns to near their centres, helped fuel growth in the number of universities and their size, and shifted the focus of much of their activity from teaching to research, for which publication is regarded as the prime index.

- The digital revolution has dramatically reduced the costs of circulating scientific papers, creating the potential to enable

> “the world-wide electronic distribution of the peer-reviewed journal literature and completely free and unrestricted access to it by all scientists, scholars, teachers, students, and other curious minds” (Budapest declaration, 2003), resulting in a call for “open access publishing”.

These trends have influenced the behaviour of scientists and of publishers in ways that have produced problematic behaviours in the for-profit sector in particular. Motives are mixed between serving the needs of science, responding to the requirements of scientists and generating a commercial profit. Profitable learned society publishers serve their science through their editing/review services and the profits they return to the work of the society. A large segment of commercial publishers offer editorial/review services to the benefit of science, but also return large profits to shareholders. The other segment of commercial publishers, often termed “parasitic” (IAP, 2022), produces ghost-written papers on non-existent research, together with fake data and images, with little if any value to science and with large profits to owners (Van Noorden, 2023).

But why do scientists choose to publish in a sector that is almost invariably more expensive than the not-for-profit sector? They may seek to be read, and therefore target so-called “high impact journals”[8] with high profiles that attract readers in particular fields. They may seek to accumulate citations and financial rewards as a demonstration of scientific excellence and prestige in a perceived publish or perish environment, or they may simply seek to publish to demonstrate research activity.

Some researchers are free to choose expensive commercial routes[9] than authors pay for publication, a “moral hazard” which avoids the normal customer control of prices. Universities tend to support these activities, which are seen as relevant to their positions in the ranking tables which are believed to support the university brand.

The search for profit by publishers and the search for recognition by scientists and universities complement each other in ways that were described by the system’s originator, Robert Maxwell, as “a perpetual financing machine” (Buranyi, 2017), leaving aside those who cannot afford to be part of the machine. Science and open science have been the losers as evidenced by the following consequences:

- Rather than digitisation lowering prices, high demand by academics has caused prices to rise at rates greater than that of inflation to levels adapted to the ability to pay of well-funded science systems (often in excess of 30-40% profit (Yup, 2023), thereby severely disabling access to the global knowledge stream in low-and-middle income countries in particular.

- The system has shown itself to be open to financial exploitation and fraud, which has created an extraordinary explosion of papers and predatory journals without significant growth in the productivity of science (Figure 3). This growth in paper writing must reduce the time spent on other university tasks (teaching, external engagement, administration), even at a time when student numbers have been increasing rapidly.

[8] In the commercial sector, four publishers Elsevier, Springer-Nature, Wiley and Taylor and Francis take 50% of the market, and because of the large proportion of relatively highly cited papers that they include, are able to negotiate large, highly lucrative deals with university libraries and national bodies (https://tidsskriftet.no/en/2020/08/kronikk/money-behind-academic-publishing).

[9] The Gates Foundation has refused to pay commercial prices, by only agreeing to fund publication as preprints. If authors wish to use for-profit outputs, they are free to do so, by must bear the costs themselves (https://openaccess.gatesfoundation.org/payment-of-publishing-fees/)

- Relatively few publishers fulfil the most basic of scientific requirements, that the evidence for a truth claim should be made available in such a way to permit reproduction and replication. Data, metadata and details of computation processes and codes are rarely provided. As academics are deterred by demands for full disclosure of evidence, journals are loath to require it in case they deter customers.

- Processes designed to maximise the integrity of science are rarely required by publishers, a particularly damaging stance at a time when science is under attack (McKie, 2024).

The desires of commercial publishers to enlarge their profits, of universities to climb rankings, of researchers to enhance their careers have all increased the obsession with publishing papers. As shown in figure 3, all have conspired during the last decade to produce a 47% growth between 2016 and 2022 in the global number of published papers (Hanson, et.al. 2023).

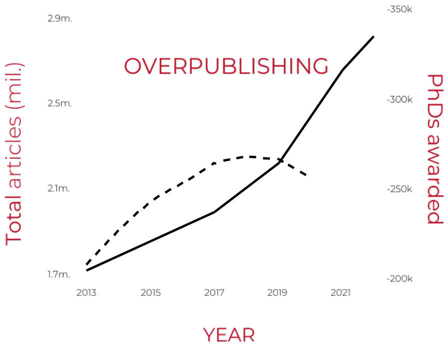


Figure 3. The explosion of publishing in the last decade and the number of PhDs awarded as an index of scientific activity (from Hanson, et.al. 2023).

During the 2016-2022 period there was little net increase in the number of PhD students globally or in the funding of science, both indicators of science activity. It implies either that scientists had become suddenly much more creative over the period, or had spent more time writing, and therefore reviewing papers: an increase in paper productivity and decrease in science productivity. Where had all those extra paper-producing hours come from? They can only reflect a massive shift of academics' time from other roles: teaching the rising generation of students, engaging with the public and in transdisciplinary work, in commercial innovation and many other intellectual tasks. It may also reflect writing to enhance bibliometrics, producing three papers when only one was formerly thought necessary.

On the positive side, the movement for open access, permitting readers to freely access content, has grown to the point where over 50% of titles are now described as "open access" (Figure 4).

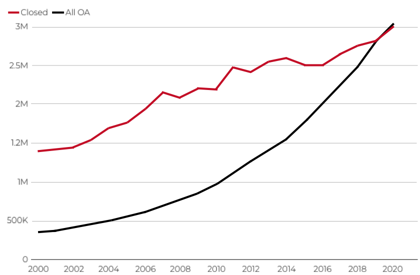


Figure 4. Trends of open access and closed access to scientific publications in the period 2000-2020. (https://www.dimensions.ai/blog/open-access-surpasses-subscription-publication-globally-for-the-first-time/)

However, open access in most cases means open to readers, not to authors, for rather than the income to commercial publishers diminishing, it has grown, by transferring payment for publication from subscriptions by readers to payment by authors through "article processing charges" (APCs). Its effect has been to strengthen the "perpetual financing machine" and to price authors in poorly funded institutions and low-and-middle income countries out of participation in and contribution to the global knowledge stream.

An important response to this has been to stimulate the creation of a "diamond publishing" scheme whereby journals and platforms do not charge fees to either to authors or readers and are community-driven, academic-led, and academic-owned publishing initiatives, inspired by the Latin American model of the academic-led, state-funded scheme of Redalyc(https://globaldiamantoa.org/manifiesto/#/).

The not-for-profit sector also includes an important variant on traditional journal publishing, represented by so-called "preprints", a scientific paper that precedes peer review and is published as a stand-alone paper rather than in a journal. Preprints originated prior to the digital revolution in response to the unacceptably long delays in getting papers published through traditional journals, particularly important in particle physics and astrophysics, areas of "big science" that were advancing rapidly (Drury, 2022).

The last few years have seen their explosive growth. Many preprints have led on to publication in conventional journals, if only to receive a conventional bibliometric assessment, although earlier this year, the Gates Foundation decided only to fund publication in preprints for the research that they have funded(https://openaccess.gatesfoundation.org/open-access-policy/). Overlay journals have recently added a peer review layer to the preprint. Their advantages are accessible pricing, speed of publication and the use of linked open peer review. They also implicitly make the case for the stand-alone paper, in that most journals are journals in the classical sense in names only. They do not play a discursive, community function but are merely convenient bundles of papers on a common topic, also acting as support for the commercial business model (Gatti, 2020).

Notwithstanding these promising developments, the overall state of scientific publishing falls far below the needs of open science for the reasons given above. A severe problem is the lack of any governance structure for scientific publishing, which might be able to regulate minimum acceptable standards, given that the lack of accepted publication standards has enabled the runaway explosion (Figure 6) of poor quality and fake science. Recently, indexing systems such as the Science Indexing System and Scopus, which tend only to index "high-impact" journals and are largely produced in the Global North, have attempted to exercise a form of quality control. It is not difficult to conceive of a better operational system that would lack such biases and place the needs of science at its heart. For example, if there were an AI-based indexing system that aided discovery of all journals and papers that met a prescribed quality level, and if only those publication systems were acceptable to universities in their judgements about excellence, the current exclusionary system with its excessive profits would be corrected and the business models of predatory journals would collapse. Again, such a move would require a governance system that would involve the science community and its key stakeholders. Are universities prepared to take up such a challenge?

6.2 Ranking

One of the bulwarks of the currently damaging culture of citation in universities is that of ranking as a means of supporting the "brand". The well-known problem with proxy measures, including citations (Strathern, 1997), is captured by "Goodhart's law", that "when a measure becomes a target, it ceases to be a good measure" (Fire and Guestrin 2019, p.2), because such targets become the purpose of strategy rather than the issues they purport to measure, and because they can be, and are, "gamed".

The ranking process is quite extraordinary. Its implication is that the rankers are the ones who know what a "good university" is, and that their ranking is a measure of that. It favours research over teaching and the natural sciences over the humanities. The process of ranking commits many of the statistical errors that we try to persuade our students not to commit. Many of these errors have been succinctly summarised by Brink (2023).

Indices of academic activity are combined to yield one index, but there are so many ways of combining them that there is no mathematical or empirical way of preferring any one to any other. There is no reason to believe that there exists a one-dimensional ordering of all the universities in the world, indeed a truer reflection of the pattern of excellence might be a scatter of points, given the diversity of university species and their varied priorities (See Section 2).

Moreover, as there is no rational system for estimating errors, a monotonic ranking is statistically impossible.

These deeply flawed systems have grown in influence to the point where they have geopolitical consequences that militate against university creativity and social potential, narrowing the university role in the interests of commercial shareholders (Hazelkorn 2015). They have become powerful and influential by exploiting the desire of universities to be highly regarded, with the consequence that it has narrowed idea of a university, and inhibited the choices it might have made to exploit its social resource. It is to be hoped that the tide is turning, and that others will follow the example of the University of Utrecht and quit (Science Business, 2023). It is high time for the universities to take a stand on the issue of the governance of scientific publishing, and the derivative issues of assessment and ranking.

7. THE CHALLENGE OF ARTIFICIAL INTELLIGENCE

Artificial Intelligence (AI) technologies have become pervasive components of university work and have already demonstrated their potential for change across the whole spectrum of university activities, in research, teaching, outreach activities and administration. They have the potential to enrich (or undermine) a new era of open science. The principal modes of application of AI are shown in [Box 4]. It is noticeable that many of its algorithms are essentially the same as used in the first phase of AI hype in the late 1950s and 60s, when hopes were not realised. It has been the enormous growth of data volumes and varieties generated by the digital revolution of the last 30 years that has provided the fuel for successful application of AI. There remains a gap however between high-level principles and practical implementation and its regulation. The key challenge is to maximise benefits while mitigating risks.

BOX 4: AI APPLICATION MODES

Machine Learning (ML) systems are trained to identify patterns in massive data volumes and extrapolate future behaviour.

Deep Learning (DL) is a version of machine learning based on neural networks used to progressively extract higher level features from data.

Natural Language Processing (NLP) generates text and speech from rules-based modelling of language together with statistical modelling of ML and DL.

Computor Vision (CV) uses MY and DL to derive information from digital images.

Expert Systems (ES) emulates rational human expert reasoning systems to solve complex problems.

Large Language Models (LLMs) acquire statistical relationships from vast amounts of text and generate new text by repeatedly predicting the next word.

Generative Artificial Intelligence (GAI) is based on DL and does not merely seek patterns, but generates new content (often of high quality text or images) based on the data it was trained on. ChatGPT is a GAI algorithm.

Robotics combines engineering and computer sciences to perform prescribed tasks to assist humans, one variety simulates how humans engage with software to perform repetitive, rules-based tasks.

Note: *The International Science Council (ISC) advocates a systems approach, considering the full context of AI's impact on individuals and society and taking into account that societal values and geostrategic interests influence the acceptance and regulation of AI (International Science Council, 2024).*

Generative AI, such as ChatGPT, is particularly important for science. It generates new content by using a machine learning model to learn the patterns and relationships in a human-created datasets and uses the derived learned patterns to generate new content. It excels in producing variations on themes well-represented in the data, such as factual summaries, genre-specific content, and programming code. LLMs interact with users in a conversational manner, often appearing helpful and confident. They provide a powerful means of summarising existing work, offering a much-improved use of time in repetitive tasks such as classification, analysis, citation, claim verification, reproduction and replication. They process vast content, creating insights and answers via text, images, and user-friendly formats and can be used to explore vast amounts of unstructured data through conversational interfaces and summarizations. All these processes have the potential to ease work in our four modal priorities for open science as summarised in Section 5. Moreover, the text is often grammatically and stylistically better than human produced text.

There is also a down-side. Although AI modes generate seemingly plausible statements based on "training" with an enormous number of texts, most lack true understanding. They currently lack process-based reasoning power and are only able to answer the question "why" if the training set contains the answer. Further, generative AI is able to rapidly create articles that can look as good as credible research articles with persuasive fake tables and figures, and require careful, line by line scrutiny to expose their fraudulence. Such articles often look as good as credible research articles, only line-by-line scrutiny can reveal the "tortured phases"[10] used in writing, with fake tables and figures. Generative AI also create new problems for reproduction and replication (Hunold and Traff, 2013), failing to learn from corrections, and can be manipulated to bypass restrictions. They can lead users to overestimate their capabilities. Understanding these design "dark patterns" is crucial for recognising their persuasive power and the susceptibility of users to their outputs.

At this stage in its evolving use, AI offers three major benefits to open science:

1. Many of the routine tasks that should be undertaken to ensure high levels of integrity (see Section 5) can be undertaken by AI systems, including ensuring that adequate information is available for reproduction and replication. They are in principle able to provide reassurance that a high level of open integrity has been achieved. Scientific publishing should evolve to the position where such reassurance becomes a condition of publication.

2. A major issue for the future of science is that generative AI has the potential to be a vital tool (Glickman and Zhang, 2024) in supporting the evolution of cross-disciplinary inter-operation (data.europa, 2024), and in ensuring that different data sets from different sources can be combined (https://codata.org/cross-domain-interoperability-framework-cdif-discovery-module-v01-draft-for-public-consultation/). Generative AI models can be used to deduce complex relationships that were not obvious to other ways of working, as exemplified by the Alphafold AI system which 1.made a fundamental advance in biology, in deducing the 3D structure of a protein from its 1D amino-acid sequence. A fundamental barrier to the development in universities of this potentially revolutionary approach lies in the fact that many LLMs are dependent on access to large volumes of published scientific work in cognate fields. Unfortunately, although the original, raw data cannot be placed under copyright, many training sets depend on using published work for which commercial publishers demand surrender of copyright (https://www.ucl.ac.uk/library/learning-teaching-support/ucl-copyright-advice/copyright-and-your-research-publications#:~:text=Students%3A%20the%20general%20position%20of,funded%20by%20an%20external%20organisation). A major part of the record of science is thus held as a private resource by commercial publishers, largely unable to be

[10] A tortured phrase is an established scientific concept paraphrased into a nonsensical sequence of words. 'Artificial intelligence' becomes counterfeit consciousness'." Please see: https://thebulletin.org/2022/01/bosom-peril-is-not-breast-cancer-how-weird-computer-generated-phrases-help-researchers-find-scientific-publishing-fraud/

interrogated by generative AI tools other than by the companies themselves. They may choose to exploit this resource as a training set for generative AI tools to release scientific knowledge that it may contain.

The preceding paragraph was written before the news that one of the big four commercial publishers, Taylor and Francis, had sold access to Microsoft to do exactly this (https://theconversation.com/an-academic-publisher-has-struck-an-ai-data-deal-with-microsoft-without-their-authors-knowledge-235203). It represents a major step in the privatisation of knowledge. It is a potentially defining step in the direction of closed rather than open science. Funders of research, universities and generations of researchers have funded, enabled and created findings as a public good, but not only have Taylor and Francis placed it behind a copyright paywall, but, without adding any value, have sold access to another commercial company as a private good, without referring to those whose labour and creativity it represents. Assuming that such potentials for profit are widely exploited, publishers, who contribute relatively little to the enterprise of science, are benefitting grossly, rather than the public sector which funds the work, the scientists who undertake the work and the universities that provide its context. Scientists and universities should regard such actions as an anathema that works against the public good. It is an action that could become a landslide and is likely to be a major barrier to the development of an important strand of open science, quite unanticipated by copyright legislation. It is an issue that should be taken up by the universities through bodies such as the IAU.

3. Generative AI has the unprecedented capacity to summarise an enormous range and diversity of scientific understanding in ways that are accessible to non-experts. In principle this is a powerful asset to the broader engagement of science with society that is central to a new era of open science and where universities are likely to have a major role. It will be important to resolve the issue in b) above if this opportunity is to be taken. Moreover, as many non-experts that have used ChatGPT can testify, doing so does not require a special expertise. Unfortunately, the training sets on which such exploration will depend are not transparent and thus impossible to assess whether they (see section 6) contain work where the level of integrity (see Section 5) is not high, or where fraudulent papers are included in the record of science. In an environment where there is public dissent about even well-supported scientific results, such pollution of the record of science is a particularly serious issue. This aspect of open science reinforces yet again the need to require minimum standards of integrity and to create a governance structure for science publishing.

A major issue of debate is the potential to create Artificial General Intelligence, meaning, in simple terms, machine intelligence that is superior to human intelligence in dealing with unprescribed tasks. Whilst generative AI produces new content by following a prescribed logic (such as playing chess, or solving for the structure of proteins), by contrast, AGI, supposing that it can be created, would produce new content without a prescribing logic. Opinion on the credibility of this is strongly divided.

There are some that regard the very concept of AGI as a mistakenly anthropomorphic view (Acemoglu, 2024), and even if it proves to be possible, a distant prospect. In contrast, Aschenbrenner (2024) writes: “The AGI race has begun. We are building machines that can think and reason. By 2025/26, these machines will outpace college graduates. By the end of the decade, they will be smarter than you or I; we will have superintelligence, in the true sense of the word”. “Everyone is now talking about AI, but few have the faintest glimmer of what is about to hit them”. If this were to materialise, the costs of human academics might seem excessive compared with AGI machines[11]. Indeed, depending on the political environment, the arguments for teaching a large student cohort because of the needs of the economy for human skills would at least be weakened. Such developments could rock the foundations of the modern liberal university as we know it. Some look forward with enthusiasm to this brave new world. Some see it as a precursor of a bleak future. Some are sceptical of its reality. Most are unaware of it. It behoves universities and their leaders to “watch this space”. Recommendations below suggest how this might be done.

[11] Universiti Sultan Zainal Abidin in Malaysia is considering the use student avatars based on their experience of operating in pandemic conditions during COVID-19.

8. Conclusion & Recommendations

Conclusion

A concerted institutional university voice has largely been absent in discussions about the opportunities (and dangers) offered by a new era of Open Science. The debate has largely been promoted by individuals and groups of academics, national academies, representative bodies of international science and UNESCO. As universities are the principal locations of publicly funded science, as they have been and are places where knowledge from the past is reassessed and new knowledge created and extended, and as the infrastructures and systems that open science needs are dependent upon university investments and management, universities should place themselves in the vanguard of this movement. The IAU holds the potential to bring leaders of universities together and create a space that facilitate debate, knowledge sharing and instruments that support and lead a new era of open science.

Recommendations

The IAU has already formally expressed support for the UNESCO Recommendation on Open Science in its policy paper: "Transforming Higher Education in a Digital World for the Common Global Good" and the work of this paper is part of its initiatives to mobilize universities to stand together and to make scientific research from all fields accessible to everyone for the benefit of scientists and society as a whole and with the view that scientific knowledge should not only be accessible but that its production should be inclusive, equitable and sustainable.

As the next steps, it is recommended that the universities endorse the four major university-specific open science priorities set out in this report, of scientific integrity, open collaboration within national science systems, openness to society, and the creation of an international open science community. Universities should:

1. Press for implementation of open processes designed to re-develop and enhance the integrity of science. In particular, it should advocate the importance of processes of scrutiny, reproduction and replication as essential to scientific self-correction to combat fraud.

2. Advocate greater collaboration within and between national science systems through national and regional sharing of data resources, equipment and archival infrastructures. Such infrastructures naturally breed collaborative research. Embedding open science concepts and practices in education and training, particularly that of young researchers, as summarised in Section 5, should be strongly promoted. Within the broader frame of the UNESCO Recommendation, the IAU could contribute to monitoring the take-up of open science and its infrastructures within universities through their global surveys.

3. Advocate for a new era of open science, enhancing openness to society, engaging with their local and regional communities, whether or not they are deeply internationally engaged, to broaden the take-up of knowledge and to combat populist attacks on scientific knowledge. This includes supporting a transdisciplinary mode of engagement, whereby scientific disciplines work

together with external stakeholders in the joint creation of actionable knowledge.

4. Encourage the transnational community of universities to discuss whether they should work together in articulating a university voice internationally. This should not venture into an expression of political views, but to articulate scientific understanding of processes. Such a stance would no doubt conflict with some political positions, but in a world that finds difficulty in distinguishing between reality and illusion, universities must be on the side of reality. A new era of Open Science must not simply reflect “western” priorities, but a true internationality, a vital antidote to a current withdrawal into antagonistic cultural blocs that inhibit attempts to address global problems as summarised in Section 5. University leaders should actively seek ways of stimulating deep collaborations, not merely international links, in order to address matters of global concern, and lobby for research funding that will support such activity.

There are several major problematic issues that that are fundamental to open science where universities have a key role to play and where IAU can be the global forum to discuss positions and actions:

5. Unrestricted access to knowledge is central to the scientific endeavour and will condition the extent to which a new era of open science becomes a reality. Scientific publishing in its current state is not well adapted to the needs of science or of the universities. Reform is essential. The voice of universities should be represented as part of a collaboration with key stakeholders, including national funders and the International Science Council in promoting and implementing reform. Key issues for reform of for-profit publishing include:

   - A financial model that discriminates on the basis of ability to pay, thereby fracturing the international science community;
   - Although some maintain high standards of editing, many apply low standards with growing evidence of fraud;
   - There is massive overproduction of scientific papers of little or no value;
   - Few publishers require evidence of essential processes that sustain scientific integrity;
   - Redesigning publication procedures and habits that inhibits the essential processes of reproduction and replication in upholding the self-correcting potential of science;
   - Should oversight or governance of publication standards be accountable to the scientific community and should the university system become involved in such a process?

6. Universities should engage with other stakeholders in reviewing and reforming the means whereby scientists are assessed, and universities are ranked. The pathologies of these systems, and the funding models that use them currently incentivise research to the detriment of other academic activities, including teaching and transdisciplinary work, create severe barriers to open science

and narrow the potential of universities for their societies. The systems of university rankings, built partly on these assessments are deeply flawed and play an inappropriate role in determining university strategies. Through the IAU, universities could consider whether to take up a critical stance with regard to rankings.

7. Artificial Intelligence technologies are of great significance to universities and to open science developments and are evolving very rapidly. The use of published work to provide training sets for AI technologies without reference to the scientists and universities that produced them should be resisted. Universities should forbid their researchers from donating copyright to publishers. It would be wise to set up a “horizon scanning group” with the remit to identify best practice on AI issues and scan for developments which could undermine the public good of universities.

9. References

ABC News.2024. Wiley's 'fake science' scandal is just the latest chapter in a broader crisis of trust universities must address. https://www.abc.net.au/news/2024-05-21/wiley-hindawi-articles-scandal-broader-crisis-trust-universities/10386866

Acemoglu, D., and Johnsom, S. 2023. Power and Progress. Basic Books UK. 546pp.

Acemoglu, D. 2024. The AI safety debate is all wrong. Project Syndicate. 5th August. https://www.project-syndicate.org/commentary/ai-safety-human-misuse-more-immediate-risk-than-superintelligence-by-daron-acemoglu-2024-08

Alberts, B. 2024. Why Trust Science? Alberts, B. 2024. Why Trust Science? Acemoglu, D., and Johnsom, S. 2023. Power and Progress. Basic Books UK. 546pp.

Baker, M. 1,500 scientists lift the lid on reproducibility. Nature 533, 452–454 (2016). https://doi.org/10.1038/533452a

Barber, M. N. 2021. Strengthening research integrity. ISC Occasional Paper, November 2021.

Bawa, Ahmed C. 2014. “Community Engagement as Fabric in Which to Weave in Teaching/Learning and Research.” In: Munck, R., McIlrath, L., Hall, B., Tandon, R. (eds) Higher Education and Community-Based Research. Palgrave Macmillan, New York. https://doi.org/10.1057/9781137385284_11

Begley, C.G. and Ellis, L.M. 2012. Rise standards for preclinical cancer research. Nature, 483, p. 531 – 533

Blake A. B. 2017. Kellyanne Conway says Donald Trump’s team has ‘alternative facts’. Which pretty much says it all. The Washington Post, January 22.

Bishop, D. 2024. http://deevybee.blogspot.com/2024/07/collapse-of-scientific-standards-at.html

Bosa, H.K, Kamara, N., Aragaw, M., Wayengera, M., Talisuna, A., 2024. The west Africa Ebola disease outbreak: 10 years on. The Lancet. Volume 12. Issue 7. 1081-1083.

Boulton, G.S. and Lucas, C. 2008. What are Universities for? Position Paper of the League of European Research Universities. https://www.leru.org/publications/what-are-universities-for

Brink, C. 2024. Academic rankings: the tide begins to turn. University World News, 24 October, 2023.

Buchanan, Bill. 2018. Are good researchers also good teachers: the relationship between research quality and teaching quality. Economics of Education Review, vol. 64. Pp. 40-49. https://medium.com/asecuritysite-when-bob-met-alice/the-secret-is-out-great-researchers-dont-necessarily-make-the-best-teachers-and-vice-versa-f95a3a14f34f#:~:text=A paper has now been,be classified as poor teachers.

Budapest Open Access Initiative Declaration. 2002. Available at: https://www.budapestopenaccessinitiative.org/ read (Accessed 17 February 2021).

Buranyi, S. 2017. Is the staggeringly profitable publishing business bad for science? The Guardian, 5th July, 2017.

Chang, A.C. and Li, P. 2015. Is Economics Research Replicable? Sixty Published Papers from Thirteen Journals Say "Usually Not". Finance and Economics Discussion Series Divisions of Research & Statistics and Monetary Affairs Federal Reserve Board, Washington, D.C.

Data.europa. 2024. Open data and AI: A symbiotic relationship for progress. https://data.europa.eu/en/publications/datastories/open-data-and-ai-symbiotic-relationship-progress.

Drucker, Joanna. 2021.The Digital Humanities Coursebook: an introduction to digital methods for research and scholarship. Routledge. 252 pp. ISBN 9780367565756

Drury, L. 2022. The normalization of preprints. International Sci- ence Council, Paris. France. https://doi.org/10.24948/2022.02.

Fire, Michael & and Carlos Guestrin. 2019. "Over-optimization of academic publishing metrics: observing Goodhart's Law in action", GigaScience, Vol. 8, No. 6., giz053.

Gatti, R. 2020. Business Models and Market Structure within the Scholarly Communications Sector. International Science Council cccasional paper, 19 pp. https://council.science/publications/business-models.

Glickman, M.,and Zhang, Y, 2024. Generative AI for Research Discovery and Summarization. Harvard Data Science Review, 6.3. https://hdsr.mitpress.mit.edu/

Greenfield, Nathan M. 2022. "Why so many people distrust science and how we can fix it." University World News. 16 August, 2022.

Hanson, Mark A., Pablo Gómez Barreiro, Paolo Crosseto, and Dan Brockington. 2023. "The strain on scientific publishing." ArXiv:2309.15884

Hazelkorn, E. 2015. Rankings and the re-shaping of higher education. 2nd Edition. Palgrave MacMillan. Basingstoke.

Inter-Academy Partnership. 2022. Combating predatory academic journals and conferences.Report. 125pp. https://www.interacademies.org/project/predatorypublishing.

International Science Council, 2024. A guide for policy-makers: Evaluating rapidly developing technologies including AI, large language models and beyond, Paris, France, International Science Council.DOI: 10.24948/2024.07 https://council.science/publications/policy-makers-guide-framework-digital-technologies/

Lawrence, R. 2023. Handbook of Transdisciplinarity: Global Perspectives. Edward Elgar Publishing. ; https://www.uu.nl/en/research/open-science

Leal, G.S.S. Guedria, W., and Panetto, H. 2019. Interoperability assessment: A systematic literature review. Computers in Industry, volume 106, pp. 111-132.

Lepore, W., L. Hall, B., & Tandon, R. (Eds.). (20 Nov. 2023). Bridging Knowledge Cultures. Leiden, The Netherlands: Brill. https://doi.org/10.1163/9789004687769

Katharine J Mach, Maria Carmen Lemos, Alison M Meadow, Carina Wyborn, Nicole Klenk, James C Arnott, Nicole M Ardoin, Clare Fieseler, Richard H Moss, Leah Nichols, Missy Stults, Catherine Vaughan, Gabrielle Wong-Parodi. 2020. Actionable knowledge and the art of engagement. Current Opinion in Environmental Sustainability. Vol. 42, p.30-37.

McKie, Robin. 3 Feb 2024, The situation has become appalling': fake scientific papers push research credibility to crisis point. Guardian newspaper. https://www.theguardian.com/science/2024/feb/03/the-situation-has-become-appalling-fake-scientific-papers-push-research-credibility-to-crisis-point)

Mitchell, N. 2022. Sector experts sound warnings over narrowing of HE routes. University World News. https://www.universityworldnews.com/post.php?story=20220428152341584.

National Academies of Sciences, Engineering, and Medicine. 2018. Open Science by Design: Realizing a Vision for 21st Century Research. Washington, DC: The National Academies Press. Hanson, Mark A., Pablo Gómez Barreiro, Paolo Crosseto, and Dan Brockington. 2023. "The strain on scientific publishing." ArXiv:2309.15884

Nature Editorial, 2021. Protect scientific collaboration from geopolitics. Vol. 593, p. 477 (2021). https://doi.org/10.1038/d41586-021-01386-0

Nehru, J. (1946). The discovery of India. New Delhi, India: Oxford University Press.Nosek, B. 2019. https://www.cos.io/blog/strategy-for-culture-change

Novotny, H., Scott, P. & Gibbons, M. 2003. Mode 2 revisited: The New Production of Knowledge. Minerva 41, 179p.

O'Hara, B. 2024. A perfect storm is hitting the humanities in British higher education. North American Conference on British Studies. https://www.nacbs.org/post/a-perfect-storm-is-hitting-the-humanities-in-british-higher-education.

Pade, N. 2022. Open Science and Research Infrastructures provide the foundation and pillars necessary to tackle global environmental issues. Open Access Government. DOI: https://doi.org/10.56367/OAG-036-9899.

Pinker, S. 20ll. The better angels of our nature. Allen Lane, London.

Pinfield, S. (2024). Achieving Global Open Access: The Need for Scientific, Epistemic and Participatory Openness (1st ed.). Routledge. https://doi.org/10.4324/9781032679259

Protzko, J., Krosnick, J., Nelson, L. et al. High replicability of newly discovered social-behavioural findings is achievable. 2024. Nat Hum Behav 8, 311–319. https://doi.org/10.1038/s41562-023-01749-9

Rahal, R.M.; Kleinberg, Bennett; Crusius, Jan; Tio, Pia. 2015. Estimating the reproducibility of psychological science. Science, vol. 349, issue 6251. https://www.science.org/toc/science/349/6251

Royal Society, 2012. Science as an Open Enterprise. Science Policy Centre Report 02/12. ISBN: 978-0-85403-962-3

Science Business. 2023. Utrecht University withdraws from global ranking as debate on quantitative metrics grows. 12th October, 2023.

Sen, A.K. (1999). Democracy as a Universal Value. Journal of Democracy 10(3), 3-17. https://dx.doi.org/10.1353/jod.1999.0055.

Stiglitz,J.E.1999.Knowledgeasaglobal public good. I. Kaul, I. Grunberg, M. Stern (eds.), Global Public Goods. Oxford University Press, New York, https://pinguet.free.fr/stiglitz1999.pdf (Accessed 15 July 2020).

Strathern, Marilyn. 1997. "'Improving ratings': audit in the British University system". European Review. 5 (3): 305-321. doi:10.1002/(SICI)1234-981X(199707)5:3<305::AID-EURO184>3.0.CO;2-4. S2CID 145644958

Tyfield, D. 2013. Transition to Science 2.0: "Remoralizing" the Economy of Science. Economic Aspects of Science, Vol. 7, No. 1. https://spontaneousgenerations.library.utoronto.ca/index.php/SpontaneousGenerations/article/view/19664. (Accessed 16 July 2020).

UNESCO, 2021. UNESCO Recommendations on Open Science. https://doi.org/10.54677/MNMH8546

UNESCO, Global Independent Expert Group of the Universities and the 2030 Agenda (2022). Knowledge-driven actions: transforming higher education for global sustainability. Retrieved November 1, 2024 from https://unesdoc.unesco.org/ark:/48223/pf0000380519

UNESCO, 2024. Open science outlook 1: status trends around the world. https://www.unesco.org/en/articles/open-science-outlook-1-status-and-trends-around-world-0

United Nations Environment Programme. 2024. Navigating New Horizons: A global foresight report on planetary health and human wellbeing. https://www.unep.org/resources/global-foresight-report).

Van Noorden, R. 2023. How big is science's fake paper problem? Nature, 623, 466-467.

Voltaire Foundation. Complete Works of Voltaire: Vol. 12, Part 1, 2018. University of Oxford.

Wike, Richard, and Shannon Schumacher. 2020. "Satisfaction with Democracy." Pew Research Center Report, Feb. 20. Voltaire Foundation. Complete Works of Voltaire: Vol. 12, Part 1, 2018. University of Oxford..

Wilbanks, J. (2006. Another reason for opening acess to research. British Medical Journal. 333 (7582): 1306–1308

Wilkinson, M., Dumontier, M., Aalbersberg, I. et al. 2016. The FAIR Guiding Principles for scientific data management and stewardship. Sci. Data, Vol. 3, 160018. https://www.nature.com/articles/sdata201618 (Accessed 21 July 2020).

World Bank. 2024. https://databank.worldbank.org/source/world-development-indicators/Series/SE.TER.ENRR

World Economic Forum. 2024. Global Risk Report. https://www.weforum.org/publications/global-risks-report-2024/

Young, N., Ioannidis, J.P.A., and Al-Ubaydi. 2008. Why Current Publication Practices May Distort Science. PLOS Medicine. https://doi.org/10.1371/journal.pmed.0050201

Yup, K. 2023. How scientific publishers extreme fees put profit over progress. The Nation. May 31, 2023.

Open Science Expert Group

Chair

Peter Aronsson
Vice-Chancellor, Linnaeus University, Sweden

Members

Noorsaadah Abd. Rahman
Deputy Vice-Chancellor, Research and Innovation, University Malay, Malaysia

Batool Almarzouq
Bioinformatician & Computational Biologist, Alan Turing Institute (UK) & OSCSA

Paola Andrea
Librarian, Independent Consultant, Colombia

Claudia Bauzer Medeiros
Professor, UNICAMP, Brazil

Ahmed C. Bawa
Professor, Higher Education, University of Johannesburg, South Africa

Fernanda Beigel
Principal Researcher & Professor, CONICET and National University of Cuyo, Argentina

Geoffrey Boulton
Emeritus Professor of Geology, University of Edinburgh, Scotland

Saray Córdoba González
Retired Professor, Universidad de Costa Rica, Costa Rica

Elena Denisova-Schmidt
Privatdozent, Research Fellow, University of St.Gallen (HSG), CIHE Boston College, Switzerland & USA

Su Nee Goh
Deputy Director, Lead for Open Science & Research Services, Nanyang Technological University, Singapore

Carolina Guzman-Valenzuela
Professor of Higher Education, Universidad de Tarapaca, Chile

Matyas Hirman
Data Steward & Open Science Support, Charles University, Czech Republic

Alina Irimia
Open Science expert, UNESCO Chair on Science & Innovation Policies, SNSPA and UEFISCDI, Romania

Pattarachai Kiratisin
Vice President for Research, Mahidol University, Thailand

Moumita Koley
Visiting Scholar, Indian Institute of Science, India

Ahmed Legrouri
Adjunct Professor, International University of Grand-Bassam, Côte d'Ivoire

Takashi Okada
Vice President for Academic Research Affairs, Sophia University, Japan

Sinéad Ryan
Dean & Vice President for Research, Trinity College Dublin, University of Dublin, Ireland

Andrea Vargiu
Professor, University of Sassari, Italy

Ricardo Villegas-Tovar
Director of the International Center for International Education, BUAP, Mexico

IAU Secretariat

Trine Jensen
Manager, Higher Education & Digital Transformation

International Association of Universities

The International Association of Universities (IAU), created under the auspices of UNESCO in 1950, is a membership-based organization serving the global higher education community through advocacy, expertise, and exchange.

IAU brings together Members from over 130 countries for reflection and collaborative action on common priorities. It is an independent, non-governmental organization in an official partnership with UNESCO (Associate status), UN ECOSOC (Consultative status), and the Council of Europe (Participatory status).

The IAU provides a forum for building a worldwide higher education community, promotes collaboration and the exchange of information, experience and ideas.

Cover design and layout: Aryan Musleh
ISBN-13: 978-92-9002-225-1

Scan the QR code to join the mailing list and learn how to get involved with the IAU's work on Open Science

International Association of Universities
International Association of Universities
t.jensen@iau-aiu.net
iau-aiu.net/technology
UNESCO House, 1 rue Miollis, Paris, France