Australian Government

AUSTRALIA'S CHIEF SCIENTIST

TRUST IN SCIENCE

Clarifying the distinctions between research integrity, research quality, excellence, and impact

CONTEXT

Science and research are at the heart of the search for solutions to many global challenges, from addressing climate change, to personalised medicine and vaccines, to ensuring new technologies are developed and deployed for good. As scientists, we strongly encourage governments and industry to reach out to the science and research community as they tackle these challenges. In this context, it is critical that science retains its high standing and public trust.

We have entered an era of declining trust in institutions, a lesser role for traditional gatekeepers of content, and increasing misinformation. As a result, science is contending with a higher tendency to question and distrust. Questioning is healthy for good science and good government, but distrust is not.

The aim of this paper is to contribute to public trust by:

- Outlining the elements of quality science.
- Describing the systems in Australia that underpin and support quality science.
- Discussing the distinction between "integrity" and "quality" in science.

The science and research sector has always had a responsibility to earn and retain trust through transparent systems of accountability, and through producing work of quality and integrity. This responsibility is especially cogent in the current context.

However, the terms "quality" and "integrity" are too often confused or used interchangeably. The result is that a debate about the quality of a particular piece of work, or the accuracy or completeness of a particular dataset, comes to be seen wrongly as a reflection on scientific integrity. This is corrosive of trust and unhelpful to legitimate scientific debate and understanding of scientific consensus.

Examples of poor scientific integrity do occur in Australia, as elsewhere. However, as Chief Scientist, I consider that Australian science and research are overwhelmingly of high integrity, and it is important that examples of poor integrity are not conflated with debates about quality and are not used to undermine trust in science.

While noting that several countries have established Offices of Research Integrity, this paper does not express a view about calls for such an office in Australia. Instead, it aims to provide clarity and context about the process of science to contribute to better public debate and understanding. If the debate can be shifted from the isolated issues of integrity to the more pressing issues of quality, I believe the public will better understand the scientific process and trust will be built and strengthened. Trust in science is built on scientific literacy.

It is equally important that the science and research community is focused on quality and a culture of constant improvement. High-quality research is research in which the question is clear, the methodology is sound, the data collection is robust, the analysis is appropriate, and the conclusions follow. High-quality research is that which is reproducible and, increasingly, it is highly collaborative and uses interoperable formats. In clarifying the components of quality research, this paper also discusses excellence and impact in research.

It is important to be clear that science and research are iterative. Findings build on work that has come before. Scientists test each other's conclusions and, through work that builds on what has come before, they refine approaches and processes to the point where a consensus is reached. Scientific consensus does not mean the weight of popular opinion; it represents the weight of evidence. This is a message that needs to be clear and reinforced. Shared understandings are a strong foundation on which public institutions can build trust.

One does not need to look far to find examples where debates about the quality of a particular paper or dataset, valid or not, are side-tracked to an attack on the integrity of a research team, or science more generally.

The COVID-19 pandemic will be top of mind for those who recall early debates about whether the virus was airborne, whether masks would be effective, the extent to which social distancing reduced transmission and the effectiveness of various treatments and therapies. None of these were issues of integrity. This was good science in action – iterative, experimental, probabilistic, and working towards a consensus.

Climate science has similarly found itself bogged down in the wrong arguments, over many decades as the weight of evidence about warming has built to the point where it is incontrovertible. Not every piece of research on this topic will meet the test of reproducibility, use the best data, or survive the findings of subsequent research, and so there may be legitimate questions about one or another aspect of the elements of quality. Again, and as with the pandemic, this is science in action, and the outcome is an excellent and substantial body of work that tells a very clear story.

Debate about water quality in the Great Barrier Reef is another example where science and scientists have borne the brunt of disagreements about the causes of reef damage and how to improve reef health. As with the previous examples, integrity is not the central issue, despite attempts to suggest otherwise.

The reef is large and diverse, and the contribution of science is to build towards a consensus based on the weight of evidence. The Australian and Queensland governments are currently working to update the 2017 Scientific Consensus Statement, using a process designed to build trust and confidence in the quality of the science. This process is an exemplar of how to bring science to policy.

More than 40 scientists are involved in the development of a new Scientific Consensus Statement, to synthesise the latest science on water quality, work that will then undergo independent technical and peer review. I, as Australian Chief Scientist, and the Queensland Chief Scientist are overseeing this review to ensure the methods used to identify and evaluate the most up-to-date scientific information are rigorous. This process connects stakeholders directly with the science and enables all parties to test questions and assumptions against the evidence. At its heart, it recognises the iterative nature of the scientific process and the importance of weighing the quality and contribution of different pieces of evidence to build a consensus. Importantly, it is an inclusive process that invites stakeholders backstage to build greater understanding of what it means to produce a body of evidence that can be described as quality science.

WHAT DO THE TERMS INTEGRITY, QUALITY, EXCELLENCE, AND IMPACT MEAN IN THE CONTEXT OF RESEARCH?

Research quality and integrity are often seen as interrelated. Surveys by the Australian Academy of Science (AAS) and Springer Nature, and the National Health and Medical Research Council (NHMRC), identified overlaps articulated by the research community when associating between "research quality" and "research integrity" [1], [2]. For example, 75% of the AAS survey respondents associated "ethical" with "research integrity", while 69% of the NHMRC respondents associated it with "research quality". Similarly, "rigorous" was associated with "integrity" by 61% in the AAS survey, and with "research quality" by 73% in the NHMRC survey.

However, research quality and integrity are not the same, and conflating these terms creates misconceptions and risks compromising the reputation of individual researchers and science more broadly. This can happen, for example, when unfounded accusations are made about the integrity of research when the real issue is one of quality, as a result, for example, of inappropriate design, methods or analysis, or a mistake in the research process. Research integrity does not equate to research quality, but both are needed to deliver research excellence and research impact. Strong processes to support research integrity and quality help to promote high standards of excellence and impact. This is the crucial foundation for establishing genuine trust in science.

Understanding the difference between research integrity, quality, excellence and impact will assist in distinguishing legitimate concerns about research integrity from questions of scientific debate. To build common understanding and support better dialogue on Australia's research and science, this paper uses the following descriptors:

- **Research integrity** is behaviour-based and requires adherence to the ethical principles and professional standards essential for the responsible conduct of research.
- **Research quality** is process-orientated and requires the best research design, the right methods, measurements, data analysis, reporting and supervision standards. This relates to the rigour of the research undertaken. Quality research is rigorous, transparent and in principle reproducible.
- **Research excellence** refers to the highest-quality research which will contribute new knowledge, complexity of thinking, new thinking, breakthroughs in understanding difficult concepts and transcendence of boundaries.
- **Research impact** is focussed on the benefits of research outside academia, such as economic, social and other benefits.

Specificity about these different aspects of the research endeavour provides a stronger foundation for a clear and constructive dialogue, especially for contested areas of science. Each is described in further detail below.

RESEARCH INTEGRITY

A useful definition of integrity is provided by S.G. Korenman, who refers to 'active adherence to the ethical principles and professional standards essential for the responsible practice of research' [3].

The Australian Code for the Responsible Conduct of Research

The Australian Code for the Responsible Conduct of Research (the Code) establishes a framework for responsible research conduct and expectations of institutions and researchers. Implementation of the Code is supported by guides on, for example, authorship, collaborative research, and disclosure of interests and managing conflicts of interest. The Code applies to institutions that are eligible to receive funding from the Australian Research Council (ARC) or the NHMRC. Some publicly funded research agencies and other government departments have also adopted the Code as a mechanism to ensure the integrity of the research they undertake or fund.

The Code does not specifically define 'research integrity'. Rather it formalises principles of responsible research conduct and the responsibilities of institutions and researchers in implementing these principles [4]. Departures from responsible research conduct – termed 'breaches of the Code' in the Australian context – can occur on a spectrum from minor inadvertent breaches to more serious breaches and misconduct such as plagiarism, falsification and fabrication. Regardless of the seriousness of the breach, research integrity is compromised whenever institutional processes or individual researchers fail to act in accordance with the principles and responsibilities outlined in the Code.

Responsibility for managing and upholding research integrity

Managing and investigating potential breaches of the Code is the responsibility of individual institutions. The ARC and the NHMRC require the institutions they fund to report on breaches of the Code and can take precautionary and/or consequential action to protect the integrity of their funding [5], [6].

Researchers and research institutions can use the guides under the Code to define responsible behaviour, inform institutional policies and processes, and design fit-for-purpose training and ongoing support to drive responsible research conduct and prevent breaches of research integrity. Research institutions implement the Code through a range of approaches including training and the establishment of processes to identify and manage potential breaches of the Code.

The Australian Research Integrity Committee (ARIC) was established by the Australian Government in February 2011 to review the processes used by institutions to manage and investigate potential breaches of the Code [7]. It is administered jointly by the NHMRC and the ARC. The Code requires institutions that receive ARC and NHMRC funding to provide training on research integrity. However, only 68% of respondents to the AAS survey could confirm that their institution provided such training [8]. This suggests that more needs to be done to ensure that appropriate training is undertaken by all researchers. Training and support should extend to professional staff and students.

Publishers of research outputs also play a role in upholding research integrity. They have policies and resources to assist authors and editors to comply with publication ethics and established processes, address any concerns and where necessary, make corrections and retractions [9]. In serious cases, the editorial boards of publishers can make decisions on future submissions by the author or author group, including being banned from publishing in a journal for a period of time [10]. The research community has driven initiatives to uphold research integrity and maintain pressure on publishers with the creation of retraction databases (such as Retraction Watch) and public scientific discussion forums (such as PubPeer) [11], [12].

RESEARCH QUALITY

Research quality relates to the way research is planned, performed and published, and the methodology, rigour and judgement applied in all aspects of the process. This includes judgments about the match between the method and the research question, selection of subjects, measurement of outcomes, protection against error and appropriateness of data analysis and interpretation. Quality research is rigorous, transparent and in principle reproducible.

Existing systems and practices to support research quality

Several existing safeguards support research quality, including the scientific method, peer review, publication processes, funding proposal assessments and supervisor standards and practices.

The NHMRC Research Quality Strategy sets out six guiding principles to ensure quality research [13].

- *Respect* – An open, honest and respectful research culture provides a supportive environment conducive to the conduct of high quality research.
- *Rigour* – Research is underpinned by robust scientific methods and avoidance or acknowledgment of biases.
- *Transparency* – Research findings, supporting data and enabling methodologies are shared and communicated openly, responsibly and accurately.
- *Accountability* – Quality research is conducted in accordance with relevant legislation, policies and guidelines.
- *Innovation* – Research oversight recognises the need for incremental and breakthrough innovations balanced with the need for necessary replication.
- *Efficiency* – Research management processes and systems designed to support research should minimise administrative burden while promoting timely reporting and synthesis to ensure that new research is built upon sound foundations.

The scientific method requires a focused hypothesis and a rigorous method to test it. It is best practice for scientists to be transparent about the method used in experiments and data analysis. Results should in principle be reproducible by others [i]. Publication of scientific research is subject to peer review both before publication (usually by anonymous peer review managed by an academic journal) and after publication (by readers who publish commentaries on papers). Publishers also have a role in promoting research quality through editorial and peer review processes. Publishers can assist in transparency through open access publishing and by requiring authors to make publicly available all data and materials necessary to replicate findings.

[i] Noting that reproducibility is not attainable in some research, where an alternative goal may be methodologies that match a set of discipline-specific measures of rigour.

The process for making funding applications also safeguards research quality. Applicants are required to outline their proposed research methodology, which is assessed. For example, the assessment criteria for ARC Discovery Projects include consideration of the 'clarity of the hypothesis, theories and research questions; and cohesiveness of the project design and implementation plan (including the appropriateness of the aim, conceptual framework, method, data and/or analyses)' [14].

Academic supervisors and research institutions have an important role in setting standards in research design and methodology to ensure quality, reliable and reproducible research. The Code has guidelines on, for example, supervision and data management to support supervisors and institutions in setting these standards [15]. This is an aspect of the quality support system that may require attention. Approximately half of respondents to an NHMRC survey did not agree that training at their institution was effective, and a recent AAS survey identified gaps in institution-provided training and support to promote research quality [16], [17].

Specifically, respondents to the AAS survey identified a need for more practical guidance on matters such as data management and curation and statistical methods, and indicated that active approaches to promote research quality, such as record keeping audits and reporting checklists, were not common practice. More active use of these and other support systems, such as independent, in-house evaluation of scientific rigour and quality before external evaluation by publishers and funding agencies, would help to increase research quality.

Preregistration of research plans in open repositories is an emerging practice in some research fields that could further enhance research quality [18].

RESEARCH EXCELLENCE

Excellent research is research that demonstrates new knowledge, new thinking, complexity of thinking, and breakthroughs in understanding difficult concepts, and may transcend discipline boundaries. Academic peers assess research excellence when reviewing funding proposals and research outputs. Peer reviewers assess the innovativeness and importance of the research and its contributions (or potential contributions) to advancing a field of knowledge.

Traditionally, metrics have been used as a catch all for measuring excellence and success. Research metrics influence the behaviours and choices of individual researchers, as publishing in prestigious journals and attracting a high number of citations can influence funding and promotion decisions. Research excellence is often equated with high citations and publication in prestigious journals, to the point that publication and citation metrics have evolved to be influential in assessing research excellence – both at the level of individual researchers and institutions.

At the individual researcher level, publication metrics such as the H-index, which is based on the number of papers published and the citation impact of these papers, have been used as indicators of research excellence and ranking individuals [19]. Journals with highly cited papers have a high journal impact factor, which is often regarded as equating to excellence. This prestige attracts more author submissions, allows these journals to select only the papers judged by peer reviewers as being of the highest standard, and therefore attracts more citations for the top-tier journals.

Other indicators commonly used to assess research excellence include previous research income, history of supervision and mentoring, patents, collaborations, and invitations to speak.

Contributions to scientific knowledge that are less easily captured include the creation of datasets or tangibles that are shared with the scientific community, and publications reporting reproduced findings. Such publications may not be well cited but make a significant contribution to knowledge by independently validating previously published findings.

Legitimate questions are raised about the extent to which the current metrics capture researcher expertise, effort, or the likelihood of beneficial impacts. These concerns are echoed by recent initiatives such as the San Francisco Declaration on Research Assessment, which 'recognizes the need to improve the ways in which researchers and the outputs of scholarly research are evaluated' [20]. An NHMRC survey identified concerns among researchers that current metrics and assessment approaches, including emphasis on publishing in top-tier journals, discourage the production of high-quality research [21].

Research metrics also influence the policies and practices of institutions. It is therefore important to ensure that the right metrics are used to incentivise practices that best serve the Australian science and research system. The Office of the Chief Scientist is undertaking a detailed analysis of these issues as part of a project in 2022-23 that will map research metrics and their impact across the research system.

RESEARCH IMPACT

Research impact is "the contribution that research makes to the economy, society, environment or culture, beyond the contribution to academic research", [22] as defined in the ARC Engagement and Impact Assessment 2018-19 National Report. Society invests in research primarily for its beneficial impacts. Demonstrating impact builds trust in science and research.

Researchers are increasingly required to plan for impact, [23] although there are challenges for measuring research impact, including the uneven and often lengthy time between research and impact. Other challenges include the complexity of factors that contribute to innovations, which can make it difficult to trace back to specific researchers, institutions and projects; and developing consistent indicators for a diverse array of impacts stemming from diverse fields of research. Measuring impact is also typically restricted to first-order impacts, with long-reaching impacts such as paradigm shifts in a research field sometimes being decades in the making.

The ARC has used an impact assessment that includes assessment of economic, social, environmental and cultural impacts through qualitative case studies supported by a range of metrics [24]. It also evaluates "research engagement", defined as the interaction between researchers and research end-users outside academia, for the mutually beneficial transfer of knowledge, technologies, methods or resources [25].

The CSIRO has developed an Impact Evaluation Guide to provide a common framework for evaluating impact across the CSIRO. CSIRO impact evaluation activities aim to "provide credible evidence of the effects of our research and innovation activities on the economy, environment and society" [26].

CONCLUSION

As our society looks to research to provide a way to solve our greatest challenges, fruitful discussion on contested research areas can be compromised when proponents have a different understanding about the meanings of research integrity, quality, excellence and impact.

For many people, integrity is at the heart of trust, and a lack of clarity in its definition can lead to unfounded questions about trust in a particular research outcome. In cases where research integrity is questioned, it should not be conflated with research quality, and conversely, where better quality research is called for, it should not be interpreted through the lens of integrity.

Science is a process of testing and experimenting. Science builds iteratively to discovery and impact. This means not every idea and not every experiment will succeed, but in an ecosystem where science and research are supported, well understood and widely shared, every idea and every experiment will contribute to the process of building deep knowledge and finding good solutions. This will support healthy dialogue and discussion across broader society and create clearer pathways to solutions that everyone can support.

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