Strengthening Research Evaluation: A Global Assessment and Dialogue

The InterAcademy Partnership

SUMMARY

The InterAcademy Partnership will undertake an evidence-based study of current research evaluation practices around the world and across disciplines, including related practices used in evaluating researchers and research institutions. The study will focus on the evaluation of discovery research in the natural sciences, engineering, and medicine. The project will examine the strengths and weaknesses of current practices in advancing the global research enterprise, explore the feasibility and merits of possible alternatives, recommend specific steps and best practices to be adopted by stakeholders, and foster a global dialogue to raise awareness and catalyze change.

The study will be led by an expert panel representing a range of countries, disciplines, and stakeholder groups. Study components will include: (1) thematic regional workshops where stakeholders will explore key issues related to the development and use of research evaluation methodologies, (2) a global survey of research enterprise participants to gain insights and perspectives on current research evaluation practices, including trends and impacts, (3) commissioned papers that develop and synthesize knowledge related to research evaluation, and (4) a web-focused effort to stimulate a global dialogue among researchers and research enterprise stakeholders about how evaluation practices can affect the quality of research and the productivity of researchers and research institutions. The final product of the project will be a report that provides recommendations and guidance for research sponsors (including governments), research institutions, scientific societies and other stakeholders.

CONTEXT

In recent decades, the global research enterprise has undergone a major growth in terms of resource inputs (highly trained researchers, research funding), outputs (scientific articles), and the number of countries supporting significant research activities (1). Research in a wide variety of fields is also being transformed by new technologies, with a growing need for collaborations that bring knowledge and perspectives from multiple disciplines to address cutting edge questions (2). As the size, scope, and complexity of research activities have expanded, and competition for funding has intensified in many countries, research sponsors have sought to improve their approaches to allocating resources and monitoring performance (3). The resulting trends in research evaluation practices have become subjects of discussion and much concern in the scientific community (4-6).

An increased focus on research evaluation has created a growing demand for quantitative and objective information that can supplement (or even replace) expert judgments as the basis for evaluating research. For example, bibliometric indicators, which quantify impact through the numbers of citations of articles published in a journal, have become widely used for purposes of evaluation. Especially influential is the *Journal Impact Factor (JIF)* developed in the 1950s by Eugene Garfield of the Institute for Scientific Information as a tool for determining which journals to include in ISI's *Current Contents* and *Scientific Citation Index (SCI)* (7). The JIF is a useful tool for helping research libraries decide on journal subscriptions. The *h-index* is a similarly constructed indicator developed in 2005 to track the citation impact of individual

authors (8). The development and wide use of such bibliometric indicators have been enabled by the emergence of comprehensive digital indexes of scientific articles that allow automated tracking and calculation.

Several serious limitations to the use of JIF and related bibliometric indicators as proxies for journal or research quality have been known and discussed for some time (9-12). The San Francisco Declaration on Research Assessment (DORA), issued in 2013, summarizes several inherent problems: (1) citation distributions within journals are highly skewed, meaning that a relatively small number of articles account for a large percentage of total citations to a given journal; (2) the JIF represents a composite of diverse article types such as primary research articles and more highly cited reviews, encouraging the publication of an excess number of reviews; (3) the JIF can be gamed by journal editors, research institutions, and individual researchers; and (4) data and methodologies that underlie the JIF are not transparent or publicly available, being privately owned by Clarivate Analytics (4). Additional complications come from the different temporal citation patterns in different fields; for example, important physics papers are highly-cited soon after publication but the rate at which they are cited falls quickly, while the citation rate of important ecology papers tends to grow over time (13).

In addition to issues that may make bibliometric indicators unreliable for the purpose of evaluating research and researchers, senior scientists and other experts have raised concerns that a widespread overreliance on these metrics is contributing to broader challenges facing the research enterprise (14-16). Some argue that evaluation relying solely or primarily on bibliometric indicators, combined with intense competition for resources, workforce imbalances, and the "winner take all" nature of much scientific competition, may create perverse incentives that contribute to researcher decisions to cut corners, use questionable statistical methods in analyzing and reporting results, or even fabricate or falsify data. Several recent trends appear to support these arguments. For example, difficulties in reproducing landmark results are being encountered in several fields (17, 18). Also, most retractions are due to misconduct, and the rate of retractions in journals is positively correlated with their JIF (19, 20). The situation is exacerbated by the practice of coercive citation, a form of gaming in which journal editors prevail upon authors to pad reference lists with superfluous citations of articles from their journals (21).

The use of bibliometric indicators in funding and personnel decisions can also encourage researchers to focus on currently fashionable topics where articles are likely to be highly cited, rather than on riskier fundamental studies (22-24). Such an effect, if it indeed exists and is widespread, would seriously impair the ability of the global research enterprise to support the most capable researchers as they seek to advance knowledge by addressing the most promising questions and topics. However, we must recognize that bibliometrics will continue to be used and evaluation procedures will need to consider carefully their role and significance for each discipline.

Taken together, the issues and problems associated with contemporary research evaluation practices present science with significant risks, in the form of systemic loss of productivity, misallocation of resources, and loss of confidence in the self-governance of science both within the enterprise as well as in the wider society. Although the specific issues vary according to different conditions within disciplines and national contexts, the growing global linkages among researchers and the international character of scholarly publishing mean that the framework of rewards and incentives created by modern research evaluation practices has a global impact. Thus, to some degree, it will be necessary to address the challenges and risks at the global level. Recent comment (25) supports this view, arguing persuasively that the time has come to go beyond DORA, and to develop credible alternatives to the current systems for evaluation.

MAJOR QUESTIONS AND ISSUES TO BE ADDRESSED

Despite the recent high-level attention to the challenges concerning current research evaluation practices, significant information gaps and issues remain that the proposed project will address:

How is evaluation currently undertaken - to what extent are bibliometric indicators used in evaluation and decision-making?

What procedures are research sponsors and employers currently using for the evaluation of research and researchers? Are there differences between disciplines, nations, and organizations in this respect? How and what sources of bibliometrics are used?

Although there have been several studies relating to evaluations in different regions and disciplines, there has been no global survey of which we are aware. Moreover, evidence bearing on how bibliometric indicators are actually used to evaluate research and researchers is limited and uneven. For example, overemphasis on JIF in research funding and personnel decisions in China has been widely reported and has even been criticized by leading Chinese scientists (26). However, there has not been any systematic examination of how China's research evaluation practices are actually implemented. In France, the Académie des Sciences issued a report in 2011 that reflects significant skepticism about the use of bibliometric indicators to evaluate individual researchers, and recommends that they be used only in combination with peer review and in situations where a number of specific conditions are met (27). It is unclear whether this perspective is reflected in the policies and practices of French research sponsors and research institutions. More recently the Royal Society, Leopoldina, the German National Academy of Sciences, and the Académie des Sciences de France issued a statement which reinforced the need for expert review to remain at the core of evaluation procedures with bibliometrics only used to inform expert judgement (28).

Likewise, there is limited information about how the use of bibliometric indicators and other research evaluation practices varies across disciplines. Much of the focus and concern about the inappropriate use of bibliometric indicators has arisen within the biomedical and life sciences disciplines, to the extent that the term "impact factor mania" has been coined to describe it (29). Some work has been done to identify discipline-specific issues and problems related to using JIF, such as limited coverage of a discipline's journals in SCI (30). There has also been some work on the variation of h- indices across disciplines in the sciences, in an attempt to introduce some sort of normalization (31).

There is a significant and growing literature that explores the use of bibliometric indicators at the macro level of national research evaluation exercises such as the United Kingdom's Research Excellence Framework and similar initiatives (3, 6, 32, 33). These assessments, which often take the form of expert panel reports, are concerned with how to benchmark national standing in particular disciplines against other countries and how to allocate funding among a nation's research institutions. Use of bibliometric indicators in these contexts raises fewer issues and concerns than use at the micro level of individual research proposals and personnel decisions, although it should be noted that the UK procedures relied largely on expert review rather than the use of bibliometrics (indeed it specifically ruled out the use of journal impact factors in any assessment although for some disciplines citation data for individual articles

was available) (34)[1]. However, insights developed in this work are relevant to the appropriate use of bibliometric indicators in micro contexts.

The Larger Research Evaluation Context and Broader Challenges to Science

How can we improve other aspects of current research evaluation systems, such as peer review? Can research excellence and quality be defined in ways that allow for the design of appropriate evaluation methods? More generally, to what extent are research evaluation practices contributing to broad challenges facing the global research enterprise such as goal displacement, misallocation of resources, irreproducibility, increased retractions, and irresponsible behavior? How does this compare with other factors such as grant funding pressures?

Any effort to develop research evaluation standards and practices appropriate to today's research environment should have a broader focus than the use or misuse of bibliometric indicators. Closely related issues should be explored, such as the effectiveness of peer review systems (35).[2] Although peer review is often conceived to be a primary alternative to the use of bibliometric indicators in research evaluation, the decisions of peer reviewers help determine which articles appear in which journals and therefore constitute the foundation for these metrics.

Peer review has served a quality control and gatekeeping function in science since the emergence of scholarly publishing in 17th century Europe. While there is a broad consensus within the global research enterprise about the continued value and necessity of peer review, there are longstanding concerns about whether peer review systems are inefficient, time consuming, or prone to bias (36). The shifts in research towards greater scale and complexity, globalization, and increased reliance on technology discussed above are also affecting the operation of peer review systems. There is increasing concern about how well peer review can be relied on to select the most significant submissions for publication and detect errors in submitted work (37, 38). With regard to assessment of individual scientists, for promotion or as candidates for academic or research positions, the quality and usefulness of reviews will depend critically on the extent to which reviewers address directly specific questions such as the scientific standing of the individual in relation to peers, and a critical assessment of a selection of that individual's publications.

Peer review relies on the expertise and commitment of the reviewers who must be recognized by their communities as having the judgement and expertise necessary for this exacting role. The choice and development of reviewers is an issue of key importance for the integrity and viability of the system.

Another important challenge to research evaluation in an increasingly global context is developing a concept of "research excellence" that will frame evaluation efforts. Excellent research can be thought of as research that is truly unusual and exceptional. Alternatively, excellence might be thought of as the expected norm, implying that all research should be excellent. The two concepts are in tension. Proceeding with the understanding that most research may be valuable but will not be excellent can be thought of as accepting mediocrity. However, in a world where there are wide variations in research capacity, forcing institutions and researchers in less developed regions and countries to focus exclusively on work that serves stronger areas may impede efforts to strengthen capacity and infrastructure.

As discussed above, scientific leaders and other experts have connected misuse of JIF and other bibliometric indicators in funding and personnel decisions with broader problems in research (4, 14, 16,

[1] Q&A response: "No sub-panel will make any use of journal impact factors, rankings, lists or the perceived standing of publishers in assessing the quality of research outputs."

22, 29). Specifying the contribution of research evaluation practices and weighting it against that of other factors that affect research environments—such as overall funding trends and a workforce oversupply—is not straightforward. These factors may well reinforce each other in contributing to a "winner take all" research reward structure in which the incentives of individual researchers and research institutions are not aligned with the performance of high quality science. Improving research evaluation practices may be a necessary, but not sufficient, step toward addressing broader challenges facing research. Comparisons between different nations may help to resolve these issues.

What existing good practices are there for research evaluation?

Evaluation measures need to be rigorous and practicable. Bibliometric indicators will continue to be used in some contexts, so how do we better use them and how can they contribute to expert review? To the extent that technical adjustments can be made in bibliometric indicators to address known shortcomings, how should such improved metrics be developed and adopted? Are new indicators needed? What additional information apart from citations should be collected and utilized? What are the key institutional and technical requirements that will enable better metrics? How do we blend the use of indicators with the expert judgement of peer reviewers?

Some of the technical problems that have been identified for specific bibliometric indicators such as JIF can be addressed by adjusting parameters. Efforts are also underway to develop substantially new citation-based indicators, indicators that—unlike the current JIF that they would replace—are based on transparent metric calculations that are open to scientifically based oversight (39).

In addition, the *altmetrics* movement is working on ways to incorporate new sources of information about the impacts of research into new indicators. These new measures go beyond the print paradigm represented by citation-based indicators, incorporating information on downloads, mentions on social media, and other online reader behavior (40, 41). However, many have criticized approaches based on social media activity as superficial and potentially even more gameable than those based on citations (42).

Creating new indicators to evaluate research and researchers will require a better understanding of technical and institutional prerequisites for their use—such as standards for digital author identifiers—and how these might be put in place.

Peer review will remain a key component of the assessment process. The value of reviews will lie in the extent to which they place in proper context the bibliometric indicators for an individual or a project. Thorough, well-focused reviews are necessarily labour-intensive, and care has to be exercised in avoiding reviewer fatigue.

Finally, efforts to improve research assessment systems should take account of the need to reward researcher behavior that advances knowledge, such as making widely available data and other products of research besides published articles. It would be shortsighted to start from the premise that a mere improvement in the manner in which published journal articles are assessed would solve the problem at a stroke. The products of research are many and varied, and effective measures for incentivising better research practices will require a broader approach that considers also, to mention a few examples, for example, data generation, sharing and curation; algorithms and associated software; the development of reagents and cell lines; and public engagement, mentoring of juniors, peer review activity, and evidence synthesis.

Research Evaluation, the Policy Environment, and Society

Who is this intended for and how is it going to be used (e.g., individuals, different levels of universities, science council, funders, funding councils, donors)? What is the role of this study in influencing policy for science?

Research evaluation methods develop and evolve within the larger policy and social context for scientific research. Researchers working in academic settings generally enjoy significant autonomy to pursue questions of interest to them. Science as an institution in society receives significant public support in many places, and at the same time is self-governing in many important respects. But like other institutions in society, science faces increasing demands for audit and accountability, placing an increased burden on evaluation systems. The development of evaluation systems that help to improve the performance of organizations and individuals, rather than inducing distortions that are counterproductive, is not straightforward (43).

For example, one of the perverse effects of the misuse of bibliometrics relates to the application at lower levels of evaluations and indicators that are specifically designed for use at higher organizational and policy levels. As this occurs, indicators will tend to push away more qualitative and detailed peer judgments, because such copying facilitates organizational accountability and eases the burden on upper level managers. The result is that individual researchers act in accordance with the organizational accountability frame provided from above and not necessarily in accord with what is most valuable for the peer community. A particular concern is the way bibliometrics may drive the behaviour of early career scientists into less creative directions by encouraging them to follow fashionable trends. Developing new methods of assessment should take the limitations of higher governance levels into account while retaining the flexibility to evaluate researchers and research groups in ways that are more appropriate to their contexts. By taking an evidence-based approach to improving research evaluation systems, the global research enterprise can actively shape these systems so that they serve the advance of knowledge and enhance the benefits of that knowledge to society.

Recommendations

What specific actions should researchers, research institutions, research sponsors, journals, and societies take to improve research assessment within their own organizational contexts and in the broader enterprise?

In recent years, there has been growing criticism of the misuse of bibliometric indicators. The most visible response was the development of DORA in 2013 (4). DORA calls for an end to use of JIF and other journal-based metrics "as surrogate measure(s) of the quality of individual research articles, to assess an individual scientist's contributions, or in hiring, promotion, or funding decisions." DORA also has specific recommendations for researchers and other constituents. As of this writing, DORA has 12,411 individual signatories and 823 institutional signatories, including universities, scholarly publishers, and research funders. It would be useful to explore the extent to which the global scientific community is aware of DORA and its contribution to changes in policies and practices.

In 2015, the Leiden Manifesto for Research Metrics put forward ten principles to guide research evaluation, including a call for quantitative evaluation to support qualitative, expert assessment rather than substitute for it, and advocating that the data collection and analytical processes underlying bibliometric indicators should be open, transparent and simple (44). There is in addition considerable

discussion and action arising out of forums dedicated to assessment of the impact of research, such as the series of meetings organized by AESIS, the Network for Advancing and Evaluating the Societal Impact of Science (http://aesisnet.com/event/ios18/).

However, experts point out that the overemphasis on indicators such as JIF and the h-index are deeply entrenched for a number of reasons, one of which is that powerful constituencies within science benefit from the resulting reward system (29), particularly with regard to the former. Creating and implementing better approaches to research evaluation will require a longer-term effort on the part of the global research enterprise. Building on DORA and other efforts to chart a course toward this goal is a primary goal of this project.

WORK PLAN

The work plan outlined below addresses the major questions and key issues identified above. Major contributions of the project will include the **development of new knowledge** and insights on major questions, **facilitation of a global dialogue that will raise awareness** of research evaluation challenges throughout the global enterprise, and efforts to **forge a global consensus** on promising steps to improve research evaluation systems that will empower scientists in every nation to help improve science in their nation.

The InterAcademy Partnership

The project will be undertaken by the InterAcademy Partnership (www.interacademies.org). IAP is a new umbrella organization that brings together three previously established networks of academies of science, medicine and engineering, namely IAP, the global network of science academies, the InterAcademy Partnership for Health (formerly the InterAcademy Medical Panel or IAMP) and the InterAcademy Partnership for Research (formerly the InterAcademy Council or IAC). Under the new InterAcademy Partnership, 138 national and regional member/academies work together to support the special role of science and its efforts to seek solutions to address the world's most challenging problems. In particular, the new IAP harnesses the expertise of the world's scientific, medical and engineering leaders to advance sound policies, promote excellence in science education, improve public health, and achieve other critical development goals.

IAP and its constituent networks have an accomplished track record in providing knowledge and advice to national governments and international organizations. Past projects have addressed problems central to the emerging Sustainable Development Goals of the United Nations, such as sustainable energy and food security. IAP has also undertaken work on scientific responsibility and research integrity, including *Doing Global Science: A Guide to Responsible Conduct in the Global Research Enterprise* (2).

IAP's procedures for assembling expert panels ensure that the appropriate expertise is brought to bear on the tasks it undertakes, and ensure disciplinary and geographic balance. Draft reports of IAP panels are reviewed by external peers, and an independent monitor ensures that reviewer comments are addressed.

Several of IAP's member academies and regional networks have undertaken related work that can be drawn upon (3, 27, 45). IAP member, The Global Young Academy, and its affiliated growing network of young academies from over 80 nations will provide important input at various stages. Issues related to research evaluation systems are of particular interest and importance to younger researchers (see

globalyoungacademy.net).

The Study Panel

The project will be undertaken by a panel of 10-12 experts with diverse disciplinary expertise, whose members represent various regions of the world and national research systems. The panel will include members with experience in research management, research funding decisions, and scholarly publishing. The panel will also include expertise on bibliometrics and other aspects of research evaluation methodologies. The panel will be assisted by a professional staff, including a study director, study coordinator, and science writer. It will be led by proposed co-chairs Professor Thokozani Majozi, Professor of Chemical and Metallurgical Engineering, Witwatersrand University, South Africa, and Professor Brian Foster, Donald H. Perkins Professor of Experimental Physics and Professorial Fellow, University of Oxford, and Alexander von Humboldt Professor for experimental physics, University of Hamburg, UK. Both have committed interest. **The co-chairs' bios are on p. 10-11.**

Regional Thematic Workshops

As part of its information gathering, the panel will organize two regional and thematic workshops of 2 days each bringing together stakeholders in the global research enterprise, including senior and junior researchers, journals, research sponsors, research institutions, journals and societies.

Part of each workshop will be regionally focused, exploring the operation of research evaluation systems and related challenges in those regions—the Americas, Africa, Asia, and Europe—as well as in individual countries. The regional session will feature discussion of concerns and problems that are being encountered, important questions that require additional evidence to address, and potential evaluation approaches that might better advance research quality and integrity. If available, the results of the global survey discussed below relevant to the region will be presented and discussed.

Each workshop will also have a thematic portion focusing on one or more of the key issues discussed above: (1) pressures on peer review and other aspects of research evaluation, (2) the use and misuse of bibliometric indicators, (3) developing and utilizing improved metrics, and (4) the broader policy and societal context for research evaluation.

Global Survey of Research Enterprise Stakeholders

The panel will oversee the development and implementation of a survey on research evaluation to gain insights and perspectives on current research evaluation practices, including trends and impacts. The survey will reach a variety of stakeholders around the world, including students, fellows of academies, young and senior working researchers, research managers, leaders of research institutions, officials of research sponsoring organizations, journal editors, society officers, and others. Insights will be gained into the evaluation of research in their disciplinary, organizational, and national contexts, and how it affects the work and behaviour of respondents. Contracts or sub-awards will be made with qualified organizations to develop the survey instrument and the online implementation. IAP will work with its constituent networks to identify and contact respondents.

Commissioned Papers

The panel will commission a series of papers that develop and synthesize knowledge related to research evaluation. The papers will address aspects of the major questions and issues discussed above. The panel and study staff will work to refine the specific topics to be addressed and identify qualified authors. The papers will be made available along with the panel's final report.

Global Dialogue to Raise Awareness and Catalyze Change

In the early months of the project, the panel and staff will develop a concise framing paper to call attention to the concerns that have been raised about modern research evaluation systems, review the current evidence base, and outline key issues and questions. The paper will be made available online, and will be accompanied by a call for input and perspectives from research enterprise participants. Existing assemblies of researchers will be encouraged to participate through their websites, email lists and social networks. Input and perspectives that the panel judges to be useful in advancing a global dialogue will also be shared online.

Final Panel Report

The panel will prepare a final report identifies best practices for research evaluation and recommends specific steps that researchers, research institutions, research sponsors, journals, and societies should take to improve research evaluation systems. The panel's work will incorporate insights from the existing literature, the regional and thematic workshops, results of the survey, responses to the call for input and perspectives, and the commissioned papers. The report will aim to move the global research enterprise toward research evaluation practices that serve science by upholding quality and integrity, while avoiding the distortions that can be created by some current systems.

Timeline and Projected Expenses

The project is expected to take 24 months.

Months 1-6

- Committee selection process
- Planning meeting among co-chairs and staff (2 co-chairs, 4 staff/consultants, 2 days)
- Schedule first committee meeting
- Begin global survey planning

Months 7-12

- Hold first committee meeting (2 co-chairs, 10 committee, 4 staff/consultants, 3 days)
- Prepare and disseminate framing paper
- Launch project website
- Plan and hold first regional workshop with second committee meeting (2 co-chairs, 10 committee, 4 staff/consultants, 4 experts, 3 days)
- Begin global survey implementation

- Assign commissioned papers
- Launch webinar series

Months 13-18

- Plan and hold second regional workshop with third committee meeting (2 co-chairs, 10 committee, 4 staff/consultants, 4 experts, 3 days)
- Continue global survey implementation
- Draft commissioned papers
- Continue webinar series

Months 19-24

- Plan and hold committee meeting 4 (2 co-chairs, 10 committee, 4 staff/consultants, 3 days)
- Revision and completion of commissioned papers
- Continue webinar series
- Prepare and review final panel report
- Release and disseminate final committee report (2 co-chairs, 2 staff/consultants, 2 days)

Co-Chair Bios

Prof. Brian Foster is an experimental particle physicist who has conducted work over many years to elucidate the structure of the proton. He is currently Alexander von Humboldt Professor at the University of Hamburg and Donald H. Perkins Professor of Experimental Physics at the University of Oxford, where he is also a Fellow of Balliol College. His current research interests are in the development of new methods of accelerating charged particles, in particular the use of plasmas excited by particle beams as an accelerating medium and in the proposal and construction of new accelerators to collide electrons and positrons to explore in particular the properties of the Higgs boson. Foster has a long-standing interest in scientific policy and research evaluation, going back to the 1980s when he was an advisor to a number of science spokesmen of the Labour party while they formed the Opposition to the UK government. He has carried out peer review of proposals and grants for many research funders across the world and is on the advisory board of many organisations. He has been involved in the UK's Research Evaluation Framework (REF) for more than a decade, first as a member of the Physics panel and then Chair of the Physics Panel for the 2014 exercise. As such he was also a member of the Main Panel that evaluated all of the physical sciences. He continues to advise UK universities on their REF submissions. Foster is a Fellow of the Institute of Physics and has served on its Council. He was elected a Fellow of the Royal Society in 2008 and currently serves on its Council. He is a Vice President of the Royal Society; as such he is a member of many committees and working groups concerned with science politics, policy and related issues, particularly the effects of Brexit on science.

Prof. Thokozani Majozi is a full professor in the School of Chemical and Metallurgical Engineering, Wits University, where he also holds an NRF/DST Chair in Sustainable Process Engineering. Prior to joining Wits in 2013, he was a professor at the University of Pretoria, where he spent nearly 10 years, and an associate professor in computer science at the University of Pannonia in Hungary from 2005 to 2009. A chemical engineer by profession, Majozi was a Commonwealth Scholar at the University of Manchester Institute of Science and Technology (UMIST) in the United Kingdom (UK) where he completed his PhD in Process Integration in 2002. He is a Fellow for the Academy of Sciences of South Africa (ASSAf), Academy of Engineering of SA, Water Institute of Southern Africa and African Academy of Sciences (AAS). He spent the early years of his career in the industrial sector, working for Unilever, Dow AgroSciences and Sasol Technology. He has received numerous awards for his research including the Zdenek Burianec Memorial Award (Italy, 2005). He is thrice a recipient of the National Science and Technology Forum Award (2006,

2011 and 2016) and twice a recipient of the National Research Foundation President's Award (2007 and 2008). In 2009, he won the prestigious S2A3 British Association Medal (Silver) and in 2010 was awarded the South African Institution of Chemical Engineers Bill Neal-May Gold Medal. He also received the AU-TWAS Award in Basic Sciences, Technology and Innovation (2012) and ORSSA Category III Award. Majozi is author and co-author of more than 200 scientific publications, including a book entitled *Batch Chemical Process Integration* published by Springer in January 2010, a book entitled *Synthesis, Design and Resources Optimization*, published by CRC Press/Taylor and Francis in 2015 and a book entitled *Understanding Batch Chemical Processes*, also published by CRC Press/Taylor and Francis in 2017.

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