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Editorial

Open Science in Three Acts: Foundations, Practice, and Implementation – First Act

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INTRODUCTION

This editorial inaugurates a series of three, dedicated to the theme of open science (CA) and its implementation in the scenario of research in Administration. In the first part, we explore the fundamental issues underpinning CA, the challenges that motivate it, such as the reproducibility crisis, and the need to engage advisors and graduate programs in adopting these principles. We call on the scientific community to recognize CA as the foundation for new researchers' reliability, dissemination, and training. In the following editorials, we move on to the practical dimensions of CA. The second text will discuss the available tools and workflows that an open scientist can incorporate into their research routine. Finally, the third editorial will address the challenge of implementing these practices, proposing a practical template to guide researchers and graduate programs in systematically adopting CA in their projects.

Contemporary science faces profound challenges regarding the reliability of its results and the democratization of knowledge. Multiple fields have experienced the so-called reproducibility crisis, which is the difficulty of reproducing published findings. More than two-thirds of researchers have tried and failed to reproduce other scientists' experiments, and about half were unable to even produce experiments themselves. Large replication efforts have revealed success rates in psychology and biomedicine, sometimes less than 40% (Baker, 2016). This crisis, widely publicized in magazines and mass media, catalyzed a movement of self-reflection in science. How can confidence in scientific results be restored? Perhaps a consensus has been adopted for CA practices (Munafò et al., 2017). The 'replication crisis' made headlines and drove the adoption of CA to improve the reliability of scientific findings.

CA proposes transparency in the stages of research — from planning to dissemination — seeking to make methods, data, and results accessible to academic peers and society. According to United Nations Educational, Scientific and Cultural Organization's definition (UNESCO, 2022, p. 7), it is

> An inclusive construct that combines diverse movements and practices, aiming to make multilingual scientific knowledge openly available, accessible, and reusable for all, to increase scientific collaborations and information sharing for the benefit of science and society, and to open up the processes of creating, evaluating, and communicating scientific knowledge to actors in society beyond the traditional scientific community.

In short, CA means sharing results and building a more rigorous, collaborative, and transparent research ecosystem in which knowledge flows freely and benefits society (UNESCO, 2022).

FROM THE REPRODUCIBILITY CRISIS TO OPENNESS AND TRANSPARENCY

The reproducibility crisis has exposed structural flaws in conducting and reporting research. Publish or perish, pressure for positive results, and non-transparent methods have accumulated robust evidence. Ioannidis (2005) questioned "Why are most research findings falsified?" — arguing that biases and flexibility of analyses produce false positives. A survey in Nature revealed that 90% of scientists agree that there is at least a 'mild' reproducibility crisis, and 70% have already failed to reproduce other people's results (Baker, 2016). These data shook confidence in the scientific literature and motivated initiatives to correct course. CA emerged as a set of practices to address these problems directly. For example, open sharing of data and code allows others to verify analyses and test secondary hypotheses, reducing inadvertent errors or fraud. Pre-registration of studies and registered reports seeks to mitigate publication and p-hacking biases by documenting hypotheses and analytical plans before data collection. Guidelines such as the TOP Guidelines (Transparency and Openness Promotion), released in 2015, recommend that journals require transparency in materials, data, and pre-registrations. These structural changes aim to put reliability back at the center of the scientific process.

The effects are already noticeable. Studies indicate that the adoption of open practices increases reproducibility. In psychology, methodological reformulation efforts have shown that rigorous practices, such as pre-registration, transparency in procedures, and adequate sample sizes, have raised replication rates of new studies to nearly 90%, a 40–50% jump from what was previously observed (O'Grady, 2023). In other words, CA has demonstrated, in practice, how to improve the soundness of scientific results. This improvement in rigor benefits academia and society, which rely on credible evidence to formulate policies, technological innovations, and health treatments.

In addition to addressing the reproducibility crisis, CA acts as a catalyst for democratizing knowledge. Promoting open access to publications and data reduces informational inequalities between researchers from different countries, academia, and the public (UNESCO, 2022). Open access initiatives, such as the SciELO library in Brazil and policies of funding agencies, have made thousands of articles freely available, expanding their reach and impact. When locked behind paywalls, scientific knowledge limits its potential to generate development and state-of-the-art mapping by generative artificial intelligence platforms. For this reason, more and more journals and institutions adopt the principle that publicly funded research results should be publicly accessible. This movement boosts scientific dissemination: researchers start to dialogue more with the public, whether through open media, institutional repositories, or participation in citizen science projects. Direct exchange with society enriches research, new data and perspectives emerge, and mutual trust is strengthened. Thus, CA fulfills a dual role: it improves the internal quality of science (via rigor and transparency) and expands its external projection (via broad access and social engagement).

TRANSPARENCY IN TIMES OF GENERATIVE ARTIFICIAL INTELLIGENCE

In this changing landscape, a new element deserves special attention: the rise of generative artificial intelligence (AGI) in scientific research. Machine learning algorithms now help analyze large volumes of data, find patterns, and even generate hypotheses. However, this tool carries risks if used in an opaque or irreproducible way. Scientists are already concerned that the non-transparent use of AGI is leading to a flood of unreliable or useless studies (Bockting et al., 2023). AI models are often described as 'black boxes': if researchers don't disclose their code, model weights, or training data, others can't reproduce or validate the results, and it can exacerbate the reproducibility crisis rather than mitigate it. For example, in the race during the COVID-19 pandemic, AGI tools were used to diagnose infections on X-rays. Still, many of these solutions failed to generalize due to a lack of proper validation (Ball, 2023).

CA offers pathways to leverage the benefits of AGI without sacrificing reliability. Open models and open data allow for community scrutiny. Recently, researchers compared open-source versus proprietary AI models, discussing how open, trained, and transparently disclosed models best align with CA principles. The conclusion is optimistic: when applied with ethical rigor, AGI can assist CA, promoting new levels of collaboration and innovation (Ball, 2023). In other words, if we embrace algorithmic transparency — disclosing model architecture, datasets used, and even opening source code — the scientific community will be able to reproduce AGI-guided findings and increase confidence in their use. There are already calls in the literature for the scientific community to establish clear standards for the use of AGI, such as living guidelines that are continuously updated, ensuring that scientists themselves supervise the use of AGI in research (Bockting et al., 2023). This intentional oversight ensures that AGI is employed as a tool for scientific acceleration rather than as an obscure shortcut. Only in this way will the integration of AGI into research reinforce — and not undermine — reproducibility.

In addition to technique, AGI raises ethical dilemmas in scientific communication. Tools like text wizards can generate essays and potentially hallucinate references or facts. Here again, CA suggests solutions: transparency labels indicating whether AGI has aided a text, guidelines for responsible use (several journals already require the declaration of use of AGI in manuscripts), and community involvement in error detection. In short, AGI should not be seen as an antagonist, but as one more reason to strengthen the culture of transparency. Integrated under open principles, it can accelerate discoveries and democratize data analysis; without this, it risks becoming another factor of opacity and crisis.

ADVISORS AS AGENTS OF CHANGE IN OPEN SCIENCE TRAINING

If CA is the path to more reliable and accessible research, how can we ensure that new generations of scientists embody these values and practices? Here, the role of graduate advisors is highlighted. Advisors don't just supervise master's and doctoral projects — they are mentors who shape the scientific posture of their students. Therefore, we argue that advisors should actively incorporate the principles of CA in training researchers at different career levels. It means teaching by example and direct guidance: showing advisees how to plan rigorous and transparent studies, encouraging data sharing and results, and valuing reproduction and open collaboration over unbridled competition.

Empirical evidence already indicates that this transmission of values makes a difference. A recent study published in *eLife* examined the practices of 211 advisor-advisee pairs in the biomedical field and found a clear pattern: students whose advisors openly shared their data were more likely to also share their data, compared to students whose advisors did not (Haven et al., 2023). In other words, the mentor's example directly influences the behavior of the future scientist. The same study observed evidence of a similar effect for open-access publications (although in this case, institutional factors also contributed). These findings confirm something intuitive: advisors work as models of conduct. They train researchers aligned with these principles if they practice and encourage CA. Conversely, if a student is never exposed to transparency practices, never participates in an open data initiative, or does not learn how to record a protocol before collecting data, they are unlikely to adopt these practices spontaneously in the future.

Therefore, we call on advisors to explicitly incorporate CA in their research groups and individual orientations. It does not imply diverting the focus from the technical content of the research area, but integrating habits of openness into the scientific routine. It means, for example, discussing data management plans from the beginning of a project, encouraging advisees to publish preprints of their manuscripts (e.g., OSF), or even engaging society (when relevant) in stages of the study. Advisors can also protect students from perverse incentives, such as the pressure for the quantity of publications, by realigning productivity metrics with quality and integrity. Ultimately, it is up to academic leaders to prepare young scientists for a career where collaboration and transparency are advantages, not obstacles. Cultural change in science passes through the graduate classroom and research groups: it is there that the next generation will learn how to do science. They learn from an early age to make it open.

FIVE STEPS TO OPEN SCIENCE-BASED ACADEMIC ADVISING

How can advisors apply CA in the training of researchers? Below, we highlight five steps based on these principles to guide the academic advising process. Each step represents a mastery of practices and values that, incorporated into the orientation, cultivate researchers who are better prepared for the current challenges of science.

Graduate programs can transform training practices by implementing these five steps in an integrated way. The student will leave the master's or doctorate with technical skills in their sub-area and as an agent for disseminating good practices — able to conduct transparent research, collaborate widely, and communicate science beyond academic boundaries. This training investment yields multiplying fruits: each new doctor trained in CA carries forward these principles, impacting colleagues, groups, and institutions wherever they go.

Thus, as a suggestion for researchers to start their research projects or orientations, we propose five stages of CA for graduate programs. These are: (1) transparent planning, (2) data and code sharing, (3) open access and communication, (4) open collaboration, and (5) ethics and integrity. Each axis corresponds to open science practices integrated into the research cycle, offering a practical roadmap for advisors and graduate students to adopt these practices systematically. The idea is that, by following these steps, research groups will make their processes more transparent, collaborative, and reproducible, in line with the FAIR principles (findable, accessible, interoperable, reusable) and with the motto 'as open as possible, as closed as necessary' (ensuring maximum openness without hurting legitimate interests, such as privacy or commercial secrecy).

(1) Transparent planning

This initial step involves making the research plan clear and accessible from the outset, through pre-registration of studies, open protocols, and other visible planning methods. Pre-registration (pre-registration of hypotheses, methodology, and analyses before data collection) is a central tool here — it improves the quality and transparency of research by allowing others to see any deviations from the original plan in the final publication, to increase the reliability of the results and prevent questionable practices such as p-hacking. In addition, making detailed protocols (e.g., experimental procedures or analysis plans) available in an open way allows colleagues and evaluators to understand precisely what will be done, strengthening reproducibility from the beginning of the project.

Thus, advisors should train students to develop robust research questions and designs, recording protocols and hypotheses in advance. Tools such as pre-registrations and pre-defined analysis plans help avoid bias and correctly interpret the results. Before the experiment begins, the advisor should encourage frank discussions about experimental design, data exclusion criteria, sample sizes, and statistical analyses. By adopting this initial transparency, the student learns that a well-planned study, with open and rigorous methods, is the basis for valid discoveries. This axis also includes familiarizing students with registered reports, in which journals evaluate the merit of the protocol before the results, focusing on methodological quality. The core message here is: clarity and honesty from the beginning of the project.

(2) Data and code sharing

This axis focuses on making the raw data, processed datasets, and source code used in the analyses available in an open, accessible, and adequately documented way. Following the FAIR principles is essential for materials to be easily findable, accessible, interoperable, and reusable by other researchers. Open data and code have multiple benefits: they enhance the quality and reproducibility of the work by allowing third parties to reproduce the findings using the same data; reduce the waste of resources and duplication of efforts; and foster collaboration and innovation, as others can reuse the data/code in new research. By sharing a dataset or script with an associated DOI, the researcher allows their work to be cited and verified independently, increasing its visibility. It is essential to ensure that the data shared is anonymized or has the proper authorizations when it contains sensitive information, aligning openness with ethics (a principle to be resumed in axis 5).

The recommendation would be that advisors teach good practices for data management and sharing organizations in reliable repositories, documentation of metadata, respect for ethical aspects (anonymization, consent), and use of appropriate licenses. Likewise, analysis codes, scripts, and software developed by the group must be made available on open platforms (e.g., GitHub or GitLab), accompanied by a README and instructions for use to allow reuse and verification. Studies have identified that making available data and materials increases citations and accelerates scientific progress, as other researchers can build on the original results instead of reinventing experiments (Mendes-Da-Silva, 2023). The advisor can establish that every student creates a repository of their project when they join, feeding it throughout the work. Ultimately, this repository (containing raw data, analysis scripts, protocol documents, etc.) remains the researcher's legacy, contributing to cumulative science. Sharing should not be seen as 'giving the gold' to competitors, but rather as multiplying the impact of the research and ensuring its verifiability.

(3) Open access and communication

In this axis, the objective is to ensure the research results are disseminated openly and widely, maximizing their reach and impact. It includes publishing articles in open access, sharing preprints, and communicating findings to different audiences. Open access publishing means anyone can read the work without barriers, increasing visibility, public engagement, and research citations. Many funders already demand open access, recognizing its role in democratizing scientific knowledge. In addition, using preprints (making the manuscript available in a repository before peer review) promotes transparency and agility in scholarly communication — subsequent changes after review are documented, making the process more transparent and traceable. In addition, dissemination is not limited to formal articles: communication in accessible language (through blogs, social media, or at extension events) is also part of CA, expanding the dialogue between research and society.

The expectation then would be that the advisors should encourage the results to be published in accessible formats: preferably in open-access journals or, if in closed journals, that the preprints of the manuscripts be deposited on open servers (SciELO Preprints, arXiv, etc.). Thus, we ensure that the knowledge generated by the student-advisor can be read and used by as many people as possible, including researchers from less favored institutions and actors outside academia (policymakers, educators, market professionals). The advisor should also encourage clear writing and active dissemination of the results. For example, teaching the mentee how to prepare non-technical executive summaries, scientific blog posts, or presentations at events open to the community. Another practice in this axis is to invite students to participate in open peer review initiatives, either as authors disclosing the evaluation received or as reviewers making their signed recommendations available. In this sense, we will insert the young researcher into the culture of open dialogue around publications. In summary, this axis promotes visibility and transparency in scientific communication, combating the enclosure of knowledge.

(4) Open collaboration

Open collaboration encourages broad partnerships during research, going beyond the immediate research group or institution. This axis values inter-institutional co-authorship, citizen science (engaging the public or communities in projects), and collaborative networking. CA, by definition, stimulates collaboration between academia, industry, public managers, and citizens, increasing creativity, trust in the scientific process, and the potential impact of findings. Inviting different actors to generate knowledge, whether contributing with data, analysis, or dissemination, creates opportunities for collective learning and innovation that would hardly occur in isolated efforts. For graduate programs, encouraging open collaboration means training researchers with a teamwork profile, capable of working on multidisciplinary projects and interacting with various sectors of society. Online tools and global communities make it easier than ever to engage external collaborators, making the research process more cooperative and transparent.

(5) Ethics and integrity

Finally, the axis of ethics and integrity runs through the previous ones, ensuring that openness does not occur at the expense of ethical principles or trust in science. The adoption of CA practices must accompany a culture of scientific integrity, honesty, transparency, and respect for ethical boundaries. It includes ensuring proper consent and privacy when sharing participant data, utilizing appropriate licenses to reuse materials, giving proper credit to third-party ideas/data, and reporting results thoroughly and without publication bias. Following guidelines and codes of ethics (such as those of the research ethics committee, COPE guidelines for publications, and principles such as CARE for data from indigenous communities) helps balance openness with accountability. In essence, this axis emphasizes that being open is also being accountable: extreme transparency comes along with increased scrutiny, so the researcher must maintain high standards of honesty. CA tools can even deter misconduct — for example, when data and code are open, there is less chance of fraud going unnoticed, and pre-registration prevents ad hoc changes in hypotheses. To guide students, graduate programs should reinforce that every open initiative is also evaluated under an ethical lens: not all data can be open (e.g., sensitive personal data), and in this case, access should be limited as necessary, without compromising the transparency of the process (e.g., disclosing privacy protocols and anonymization methods used).

CONCLUSION: A PATH OF NO RETURN, A PROMISING FUTURE

Incorporating CA as a central strategy for scientific development, the dissemination of knowledge, and the training of researchers represents a path of no return — and a promising future. The challenges that motivated this movement, such as the reproducibility crisis and disruptive innovations such as artificial intelligence, are still present and will require constant adaptation. However, the trajectory demonstrates that openness can constructively address such challenges. More than that, CA reimagines scientific work: from an ethos of secretive competitiveness to a culture of transparent collaboration. This new paradigm benefits not only the credibility of science in the eyes of society by making it more reliable and understandable, but also enhances the efficiency of scientific progress through the unrestricted exchange of knowledge and resources.

As a purposeful editorial, we leave a clear message to the scientific community in general, especially to the trainers of new researchers: embrace CA as a daily practice and fundamental value. Each advisor who embraces these ideas helps create a next generation of scientists committed to the quality, integrity, and public utility of research. Every author who publishes openly, every reviewer who acts transparently, and every group who shares their data contribute to an ecosystem in which discoveries accumulate more solidly and knowledge circulates without barriers. There are still obstacles — infrastructure to improve, policies to implement, and, above all, minds to convince. The trend is irreversible; global initiatives, such as the 2021 UNESCO Recommendation on Open Science, and local initiatives, such as the new CAPES evaluation criteria that value open data, show that institutions adhere to this vision.

Each stage — from transparent planning to integrity — acts complementarily, covering the entire research cycle and fostering a more open, collaborative, and responsible academic culture.

CA represents a promising and irreversible path to strengthening the integrity and impact of scientific research. The conceptual discussions and call to action presented in this editorial constitute the first step of further exploration. In upcoming editorials, we will provide practical guidance and concrete tools to assist researchers and graduate programs in transitioning to a more open and transparent workflow. The second text will detail the tools and practices, while the third will propose a structured model to guide the effective implementation of the principles of CA in the daily life of research and the training of new scientists. By embracing CA in all its dimensions — conceptual, practical, and implementation — we will build a more trustworthy, collaborative, and beneficial future of science for all of society.

We conclude by calling on our fellow researchers, young or old: let's make CA not just a set of guidelines, but the essence of our scientific conduct. By cultivating transparency, collaboration, and sharing in research, we will strengthen the foundations of science, making it more solid internally and more relevant externally. This way, we will fulfill our double social role with excellence: to produce reliable knowledge and disseminate it for the common good. This is the science we want to see flourish in the coming decades.

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