# Open science emphasizes practices of research reproducibility and replicability.

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## Abstract

In recent years, attention to the reproducibility and replicability of scientific research has been increasing across multiple disciplinary domains. This article explores the definitions of research reproducibility and replicability, the current crisis they face and its underlying causes, and proposes corresponding solutions. It also emphasizes the crucial role of research libraries in promoting reproducibility and replicability, as well as the significance of open science in advancing this agenda. Measures such as data sharing, code availability, and standardization of computational environments can effectively enhance the transparency and verifiability of scientific research, thereby strengthening its overall quality and credibility. In view of the impact that the scientific reward system has on the reproducibility and replicability crisis, this paper proposes the prospect of incorporating reproducibility and replicability badges as part of literature metadata, aiming to guide researchers toward greater emphasis on these two dimensions.

## Full Text

## Preamble

### Practices of Open Science Emphasizing Research Reproducibility and Replicability

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**Abstract**
In recent years, there has been growing concern regarding the reproducibility and replicability of scientific research across multiple disciplines. This paper delves into the definitions of research reproducibility and replicability, examines

the current crises faced, and identifies their underlying causes. It further proposes corresponding solutions. Additionally, this paper emphasizes the pivotal role of research libraries in enhancing research reproducibility and replicability, as well as the significant impact of Open Science in advancing this process. Measures such as data transparency, code sharing, and the standardization of computational environments can effectively improve the transparency and verifiability of scientific research, thereby strengthening the overall quality and credibility of scientific endeavors.

Furthermore, this paper discusses the influence of the scientific reward system on the reproducibility and replicability crises, and puts forward the prospect of including reproducibility and replicability badges as part of bibliographic metadata, aiming to guide researchers to place greater emphasis on these aspects.

**Keywords**
Open Science; Research Reproducibility; Replicability; Research Libraries; Scientific Reward System

## 1. Introduction

Since the late 2000s, concerns about the crisis of reproducibility and replicability in scientific research have intensified across multiple disciplines, including psychology, biology, and economics. As research in these fields has deepened and evolved, an increasing number of scholars have begun to question and reflect on existing problems in current scientific research, particularly expressing concerns about the reliability and repeatability of experimental results. In 2021, UNESCO explicitly identified reproducibility as one of the key principles for realizing the value of open science in its Recommendation on Open Science. This principle emphasizes the transparency and verifiability of experimental results throughout the scientific research process, which is crucial for enhancing the overall quality and credibility of scientific research. Simultaneously, UNESCO's recommendation has further promoted global attention and discussion on the reproducibility crisis, prompting more scholars and research institutions to consider and take action to address this challenge.

## 2. Definitions of Research Reproducibility and Replicability

Research reproducibility refers to the ability of different researchers, or the same researcher at different times, to obtain consistent results when using identical input data, computational procedures, research methods, code, and analytical conditions. This concept emphasizes the repeatability and consistency of experimental conditions and processes, representing a critical manifestation of scientific reliability.

Replicability, in contrast, refers to the consistency of research findings across different studies addressing the same or similar scientific questions, even when

each study independently acquires data and employs potentially slightly different research methods. Replicability requires not only the reliability of research results but also emphasizes the general applicability and verifiability of scientific research, forming the foundation upon which scientific theories gain widespread acceptance and application.

## 3. Causes of the Reproducibility and Replicability Crises and Proposed Solutions

The causes of the reproducibility crisis are complex and multifaceted. Primary among them is the non-disclosure of data and code. Many researchers, for various reasons such as protecting intellectual property or concerns about competitive pressure, choose not to disclose their research data and code, making it difficult for other scholars to verify and replicate their findings. Additionally, insufficient documentation of computational environments and dependent software represents another significant factor affecting reproducibility. Over time, software version updates and changes in hardware environments can all impact the repeatability of research results. The issue of digital resource obsolescence similarly cannot be ignored, as outdated databases and software tools may prevent the reproduction of historical research.

The replicability crisis stems mainly from publication bias and questionable research practices, such as p-hacking. Publication bias often results in only those studies with significant findings receiving publication opportunities, while those that fail to replicate or yield non-significant results are frequently overlooked or rejected. This bias seriously distorts the true landscape of scientific research and substantially reduces replicability. Simultaneously, some researchers resort to p-hacking behaviors—including selective reporting and data manipulation—in pursuit of significant results, further exacerbating the replicability crisis.

At its root, the priority rule within the scientific reward system has substantially contributed to the lack of incentives for reproducibility and replication. Under the current scientific reward system, scientists who are first to discover new phenomena often receive substantial recognition and rewards, while those who conduct subsequent replication studies frequently struggle to obtain adequate acknowledgment. This mechanism undoubtedly discourages scientists from engaging in reproducibility and replication research, thereby intensifying the crises.

To address these crises, the academic community and research institutions must work collectively to promote the open sharing of data and code, improve documentation of computational environments and software dependencies, and strengthen the maintenance and updating of digital resources. Simultaneously, reform of the scientific reward system is necessary to establish a more equitable and reasonable evaluation mechanism that incentivizes scientists to actively participate in reproducibility and replication research, thereby promoting the healthy development of scientific research.

## 4. The Role of Research Libraries

Research libraries play a pivotal role in addressing the reproducibility and replicability crises. First, through education and outreach activities, research libraries can significantly enhance researchers' awareness of reproducibility and replicability. This includes developing specialized teaching materials, inviting domain experts to deliver lectures, and organizing relevant seminars and workshops. These activities not only help researchers deeply understand the importance of reproducibility and replicability but also facilitate their mastery of methods and tools for improving these aspects.

Research libraries also perform critical functions in information infrastructure development. To address the opacity of research data and computational environments, research libraries can actively participate in establishing knowledge repositories for research data sharing. These repositories not only provide researchers with a centralized platform for storing and sharing research data but also ensure the long-term accessibility and availability of data. Furthermore, research libraries can assist in resolving execution environment and software dependency issues by providing standardized computational environments and software dependency management tools to help researchers ensure the reproducibility of their work. These initiatives are essential for enhancing the overall quality and credibility of scientific research.

## 5. The Contribution of Open Science

Reproducibility and replicability constitute important foundations for open science. If research results cannot be reproduced or replicated by others, then the knowledge sharing and collaborative innovation advocated by open science cannot be realized. Therefore, ensuring research reproducibility and replicability is a prerequisite for achieving the goals of open science.

Open science helps enhance research reproducibility and replicability. By opening research data, code, and methods, other researchers can more easily verify and replicate previous work, thereby identifying potential problems and making improvements. Simultaneously, this spirit of openness and collaboration helps promote the standardization and normalization of research methods, further improving reproducibility and replicability.

Data openness and sharing provide the foundation for other researchers to verify and replicate previous work. When research data are made public, other researchers can use the same data for reproducibility studies, thereby evaluating the reliability and validity of original research. Beyond data, open science also encourages researchers to disclose their code and analytical methods, helping other researchers understand the research process and conduct replication studies under the same or similar conditions. Additionally, open science promotes cooperation and exchange among researchers. By sharing data and methods, researchers can more easily establish collaborative relationships and jointly solve scientific problems. This collaboration not only helps improve research

reproducibility and replicability but also promotes innovation and progress in scientific fields.

## 6. Conclusion

Research libraries play an irreplaceable role in promoting the improvement of scientific research quality. Through implementation of educational activities and information infrastructure development, they effectively enhance researchers' emphasis on and proficiency in research data management. These activities not only strengthen researchers' understanding of reproducibility and replicability but also provide them with practical guidance and support.

However, we must also confront a deeper underlying problem: the scientific reward system serves as a fundamental cause of the reproducibility and replicability crises. The current scientific reward system often overemphasizes research novelty and significance while neglecting the importance of reproducibility and replicability in scientific research. This orientation, to some extent, discourages researchers from conducting reproducibility and replication studies, thereby exacerbating the crises.

To fundamentally address this issue, the research library community hopes to contribute to future academic information dissemination by promoting the display of reproducibility and replicability badges as part of bibliographic metadata. This would not only enable researchers to more intuitively understand the reproducibility and replicability status of a study but also guide them to place greater emphasis on these aspects in their own research, thereby driving the entire scientific research field toward a healthier and more sustainable direction.

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*Note: Figure translations are in progress. See original paper for figures.*