

KNO-021 · Open Science and Reproducibility

KNO · Ways of Knowing

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Article Abstract

Scientific claims become easier to inspect when the materials needed to understand, repeat or challenge them are accessible. Open science is the family of practices that tries to make that inspection possible: sharing data and code where appropriate, describing methods precisely, distinguishing exploratory from confirmatory analysis, preserving versions and making corrections visible. Reproducibility and replicability are related but not identical. A result can be computationally reproducible and still be wrong, while an independent study can fail to replicate for reasons that do not reduce to misconduct or incompetence. This article asks which parts of a scientific result must remain inspectable for later researchers to reconstruct the analysis, test the claim under new data and discover where disagreement enters. It treats openness as an infrastructure for criticism, not as a certificate of truth.

In 60 Seconds

Open science is not one switch labelled “share everything.” It is a set of controls that make scientific work more inspectable. Reproducibility usually asks whether the same data and computational procedures can yield the same result; replicability asks whether new data collected for the same question produce results that are consistent within the relevant uncertainty.[1,2] Preregistration can separate predictions from analyses chosen after seeing the data, but it cannot make a weak design strong.[3] Registered reports move part of evaluation before results are known, while open data and code let others inspect transformations, exclusions and implementation.[4] None of these practices guarantees truth. Their value is procedural: they expose more of the path from observation to claim, preserve alternatives that would otherwise disappear, and make correction cheaper. Openness also has limits: privacy, security, consent, intellectual property and the burden of curation can justify controlled rather than universal access. The goal is auditable science, not frictionless disclosure.

Why This Question Matters

Modern science often depends on datasets, scripts, instruments and decisions that are invisible in the final paper. When only the narrative survives, later researchers may be unable to tell whether a disagreement comes from data, preprocessing, statistical choices, software, interpretation or a genuine difference in nature. Open-science practices try to preserve those decision points. They matter because criticism is one of science’s error-correcting mechanisms, but criticism works only on what can be inspected. The same practices also expose a tension: openness can increase auditability while creating new obligations around privacy, governance and long-term stewardship.

1. Reproducibility Is Not Replication

The Question If two researchers obtain the same numerical result, what exactly has been reproduced: the computation, the observation, or the claim? The answer depends on which inputs, procedures and conditions remain fixed, and which are allowed to change during the new test.

The National Academies distinguishes reproducibility from replicability for practical clarity. Reproducibility concerns obtaining consistent results with the same input data, computational steps, methods and conditions of analysis; replicability concerns new studies addressing the same question with newly obtained data.[1] Goodman, Fanelli and Ioannidis likewise show that the vocabulary has been used inconsistently across fields and warn against treating “reproducible” as a synonym for “true.”[2]

This distinction separates two different failure modes. If the same files and code do not regenerate a published table, the problem may be missing dependencies, undocumented preprocessing, version drift or implementation error. If a new study disagrees, the explanation may instead involve sampling, measurement, context, effect heterogeneity or a false original claim. The diagnostic work begins by asking which kind of sameness was expected.

Claim C01. Reproducibility and replicability test different forms of consistency. [1,2]

Claim C10. Reproducibility should not be used as a synonym for truth. [2]

Where That Leaves Us

Reproducibility and replication test different links in the evidential chain. Matching an old computation checks whether the reported analysis can be reconstructed; collecting new data tests whether the claim survives a fresh encounter with the world. Neither result is a truth certificate. The next question is therefore what must be preserved so that reconstruction is possible at all.

2. A Paper Is Not the Whole Analysis

A paper compresses a much larger process. Raw observations are selected, calibrated, cleaned, transformed and summarized before they become a figure or coefficient. Software libraries contribute defaults; exclusion rules remove cases; intermediate files carry state. When those layers disappear, the publication can remain readable while the analysis becomes impossible to reconstruct.

Reproducible work therefore needs more than prose. Depending on the field, it may require data or a controlled-access substitute, code, environment information, parameter choices, calibration records and a mapping from outputs back to inputs. The point is not to preserve every keystroke. It is to preserve enough of the dependency graph that another competent researcher can identify how the reported result was produced.[1,4]

Claim C02. Reproducibility can fail because data, code, dependencies or analysis conditions are not reconstructible. [1]

Where That Leaves Us

The scientific object under review is often larger than the article that describes it. Data, code, parameters and provenance can carry causal responsibility for a result even when they occupy no printed page. Preserving them makes hidden choices inspectable. That leads directly to the next problem: some choices should be recorded before the result is known, not reconstructed afterward.

3. Preregistration Separates Prediction from Retrospection

Data can suggest hypotheses after they have been observed. That is scientifically useful, but it is different from testing a prediction that existed before the observation. Nosek, Ebersole, DeHaven and Mellor describe preregistration as a way to make that temporal distinction visible by recording hypotheses and analysis plans before outcomes are inspected.[3]

Preregistration does not eliminate exploration, and it does not make an analysis correct. Plans may be underspecified, measurements may fail, and justified deviations may be necessary. Its value is that a later reader can see which decisions were prospective and which were responses to the data. That changes the interpretation of evidential strength without forbidding discovery.

Claim C03. Preregistration can make the timing of hypotheses and analysis choices visible. [3]

Claim C04 - Declared synthesis. Preregistration does not by itself establish design quality or truth. **Declared synthesis:** [3] supports preregistration as a procedural commitment made before outcomes are known; the further clause that preregistration does not itself establish design quality or truth is the synthesis.

Where That Leaves Us

Preregistration is a timestamped distinction, not a quality seal. It preserves when a hypothesis or analysis choice entered the workflow, so readers can separate prediction from data-dependent adaptation. That can reduce ambiguity about evidential status while leaving exploration legitimate. The next step moves the same logic into publication: can evaluation begin before the result is known?

4. Registered Reports Change the Order of Evaluation

A conventional article is usually reviewed after the main results exist. Registered-report formats move an important part of review earlier: the question, design and planned analysis can be assessed before the outcome is known. Munafò and colleagues include this among reforms intended to reduce opportunities for selective reporting and hindsight-driven storytelling.[4]

Changing the order does not guarantee a useful question or flawless execution. It changes incentives and the evidential record. A null result from a design accepted in principle is less vulnerable to disappearing because it is unexciting, while deviations from the accepted plan can be documented rather than hidden. Publication becomes more closely tied to the quality of the question and method than to the direction of the outcome.

Claim C05. Registered-report style reforms shift evaluation of questions and methods earlier in the research process. [4]

Where That Leaves Us

Registered reports show that openness is partly about chronology: preserving what was decided before outcomes could influence those decisions. They reduce one route by which the published record can become selectively filtered, but they do not remove all filters. The next question is what happens after publication, when another researcher needs access to the material that made the result possible.

5. Open Data and Code Make Transformations Inspectable

Sharing data can allow others to check coding, exclusions, transformations and alternative analyses. Sharing code can expose how a published number was actually computed rather than how the method was described in prose. Together they reduce the distance between the claim and the operations that produced it.[1,4]

But “open” is not enough. A file without variable definitions, provenance or version information may be technically downloadable and scientifically unusable. Code that depends on undocumented software versions may fail years later. Openness therefore needs curation: identifiers, metadata, licences, dependency information and preservation strategies. KNO-019 established why structured records need context; open science adds the requirement that the context remain accessible to criticism.

Claim C06. Open data and code can expose transformations and implementation choices to scrutiny. [1,4]

Claim C07 - Declared synthesis. Open access without metadata, provenance and version context can be scientifically insufficient. **Declared synthesis:** [1] supports the importance of metadata, provenance and version context for reuse; the judgment that access alone can therefore be scientifically insufficient is the synthesis.

Where That Leaves Us

Open materials extend the inspectable object from the paper to the workflow, but access without context is weak evidence infrastructure. Data and code need metadata, versions and provenance if they are to remain interpretable. This turns openness into a stewardship problem as well as a disclosure problem. It also raises a limit: some scientifically important materials cannot responsibly be made public without restriction.

6. Openness Has Legitimate Limits

Human-subject data can contain information that participants did not consent to make public. Ecological locations can expose endangered species. Security-sensitive methods and contractual obligations can restrict dissemination. Open science therefore cannot mean universal public release of every underlying object.

The stronger principle is inspectability under appropriate governance. De-identification, secure enclaves, data-use agreements, synthetic data, controlled repositories and independent access committees can preserve some auditability without pretending that risk is zero. The design problem is to make restrictions explicit and proportionate so that “cannot be public” does not silently become “cannot be checked.”

Claim C08. Legitimate privacy and security obligations can justify controlled rather than unrestricted access. [1]

Where That Leaves Us

Open science is compatible with controlled access when unrestricted disclosure would violate legitimate obligations. The epistemic requirement is not maximal publicity but a documented path by which qualified scrutiny remains possible where feasible. That makes governance part of evidence infrastructure. The next issue is correction: once errors are found, does the record preserve the fact that the scientific object changed?

7. Versions and Corrections Are Part of the Evidence

A corrected dataset, revised script or retracted conclusion is not the same scientific object as the version that existed before the change. Persistent identifiers, versioned repositories and correction notices make that distinction recoverable. Without them, later users may unknowingly combine claims from one version with data or code from another.

Good correction practice therefore does more than replace a file. It preserves enough history to show what changed, why it changed and which conclusions are affected. This is a form of institutional memory. It allows science to change its mind without erasing the path by which the change occurred. KNO-024 will return to the preservation problem from the opposite direction: what disappears when such records do not survive?

Claim C09 - Declared synthesis. Versioning and correction records distinguish changed scientific objects from earlier versions. **Declared synthesis:** [1] supports explicit version and correction context; treating those records as what distinguishes a changed scientific object from its earlier manifestation is the synthesis.

Where That Leaves Us

Versioning makes correction visible as a change in the evidential object rather than a silent replacement. That matters because later researchers must know which data, code and interpretation a claim refers to. A transparent correction history is evidence about the history of evidence. The final question is how all these practices should be judged without turning openness itself into a badge of correctness.

8. Open Science Is an Error-Correction Infrastructure

Open practices do not guarantee that a dataset is unbiased, a model is well specified or a conclusion is true. They change which mistakes can be found and by whom. Munafò and colleagues frame reproducible practice as a system of interacting reforms rather than a single cure.[4] The National Academies similarly treats reproducibility and replicability as properties to investigate, not as simple verdicts on scientific worth.[1]

The strongest case for openness is therefore procedural. A claim accompanied by inspectable materials exposes more possible points of challenge. An unreplicated result can be diagnosed more precisely. A correction can propagate to the objects that depend on it. The gain is not certainty; it is a shorter path from disagreement to diagnosis and from diagnosis to repair.

Claim C11 - Declared synthesis. Open-science practices can shorten the path from disagreement to diagnosis by exposing more of the evidential workflow. **Declared synthesis:** [1,4] support opening records and workflows to inspection and reuse; the claim that this can shorten the path from disagreement to diagnosis is the synthesis.

Claim C12 - Declared synthesis. Open science is best treated as error-correction infrastructure rather than a truth certificate. **Declared synthesis:** [1,2,4] support transparency, reproducibility practices and correction mechanisms; describing open science overall as error-correction infrastructure rather than a truth certificate is the synthesis.

Where That Leaves Us

Open science is best understood as infrastructure for organized criticism. It preserves more of the route from observation to claim, distinguishes some decisions by when they were made, and makes corrections easier to trace. These properties can improve reliability without proving truth. The boundary is now clear: KNO-020 owns review and consensus; KNO-021 owns inspectability, reproducibility and correction practices.

What We Know, and How

- Reproducibility and replicability test different kinds of consistency and should not be treated as synonyms.[1,2]
- Preregistration can make the timing of hypotheses and analysis choices visible.[3]
- Open data, code and provenance can make more of an analysis inspectable, but access without context is insufficient.[1,4]
- Versioning and visible corrections preserve which scientific object a claim refers to.

What We Still Don't Know

- How much each open-science intervention improves reliability across different disciplines and study designs.
- Which combinations of openness and controlled access best preserve both auditability and legitimate privacy.
- How long contemporary research objects remain executable as software and hardware ecosystems change.
- How incentive systems alter the real use, rather than nominal adoption, of open practices.

What Could Change Our Minds

- Large cross-disciplinary evaluations showing that a widely promoted practice adds no auditability or reliability under realistic use.
- Evidence that a control intended to reduce selective reporting systematically creates larger distortions than it prevents.
- New privacy-preserving methods that make currently restricted forms of scrutiny safely routine.
- Long-term preservation studies showing that current repository and versioning practices fail to keep research objects interpretable.

If You Remember Only One Thing

Open science does not certify truth; it preserves more of the evidential path so that other people can inspect, reproduce, challenge and correct it.

Related Articles

- KNO-019 · Data, Tables and Records
- KNO-020 · Review, Consensus and Disagreement

- KNO-024 · Lost Knowledge and Preservation Bias

References

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