



NISO RP-31-2021

Reproducibility Badging and Definitions

*A Recommended Practice of the
National Information Standards Organization*

Approved: January 15, 2021



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Contents

Section 1: Purpose and Scope	1
1.1 Overview.....	1
1.2 Summary of Purpose and Scope	1
Section 2: Badge Definitions	3
2.1 Open Research Objects (ORO)	3
2.2 Research Objects Reviewed (ROR)	3
2.3 Results Reproduced (ROR-R)	4
2.4 Results Replicated (RER)	4
Section 3: Badge Characteristics	5
3.1 Placement and Discovery	5
3.2 Badge Metadata	5
3.3 Badge Validator.....	5
3.4 Badge Help.....	6
3.5 Badge Design.....	6
3.6 Badge Revocation	6
Section 4: Future Work	7
Appendix A Currently Used Badges and Badge Hierarchies	8
Bibliography	15

Foreword

About this Recommended Practice

Reproducibility, the practice of validating prior research through the sharing of data and methods, is a topic that has been discussed within the scholarly research community for more than twenty years. Recently, funding agencies and publishers have accelerated efforts to stimulate reproducibility.

Critical to the issue are the definitions used to define the various levels of reproducibility, and agreement on a standardized badging scheme that can be applied in the publishing process (and perhaps used as a currency in the academic rewards culture). As publishers and researchers begin to implement reproducibility practices, recognition and reward schemes and the related taxonomies are developing on an ad hoc basis, creating a need for some standardization.

This recommended practice is an effort to develop common recognition practices, vocabulary, and iconography used to facilitate the sharing of data and methods.

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Section 1: Purpose and Scope

1.1 Overview

For several years now, stakeholders across the scholarly research community—researchers, funding agencies, learned societies, and publishers—have discussed ways to transform the publishing of research results from narratives to actionable research tools, a practice that has come to be known simply as “reproducibility.”

In early 2018, the U.S. National Academies of Sciences, Engineering, and Medicine (NASEM) appointed a committee of fifteen members, representing a wide range of expertise, to examine the issue of scientific reliability. The work of the committee resulted in a landmark report, *Reproducibility and Replicability in Science* (“the NASEM Report”), published in 2019.¹ The NASEM Report provided recommendations to researchers, academic institutions, publishers, and funders on steps they can take to improve reproducibility and replicability in science. The report defines reproducibility as “obtaining consistent results using the same input data, computational steps, methods, and code, and conditions of analysis.”

In the spirit of the NASEM effort, in March 2019, a group of research-publishing stakeholders formed a committee under the aegis of NISO to develop a set of recognition standards to be universally deployed across the scholarly publishing output. The work of that group resulted in this recommended practice.

Reproducibility is a process as much as an end. It is critical to define the various levels of reproducibility and agree on a standardized badging scheme that can be applied in the publishing process (and perhaps used as a currency in the academic rewards culture). Several badging schemes are already in use by journals and other contributors to the scholarly record to indicate reproducibility, openness, and artifact status, which indicates a general level of high interest in the activity.

We find that this common usage of badging schemes in the community warrants creation and implementation of a harmonized set of badge definitions regarding reproducibility. Some badge labels and definitions currently in use are contradictory, impeding efforts to communicate reproducibility standards and creating confusion regarding publication submissions and badging in the scholarly community.

We build on the current siloed reproducibility badging efforts that have occurred in disparate scholarly communities and offer a set of unified recommended practices regarding reproducibility badging for scholarly publications. We seek to provide guidance on badging standards to avoid proliferation and conflicts among multiple badges and badge definitions in the scholarly community.

1.2 Summary of Purpose and Scope

- Target audience: Scholarly research publishing community—publishers, authors, editors, reviewers
- Recognition badges and definitions for use in the publications process—to be assigned to a published paper that meets varying degrees of reproducibility activity
- Harmonize the various badging efforts in place, to create a unified standard

¹ National Academies of Sciences, Engineering, and Medicine, 2019. *Reproducibility and Replicability in Science*. Washington, D.C.: The National Academies Press. <https://doi.org/10.17226/25303>.

NISO RP-31-2021, Reproducibility Badging and Definitions

- Reproducibility badging practices are managed as part of the publishing process by learned societies and publishers
- Outside the scope of this effort were details of the process for verifying results

Section 2: Badge Definitions

We recommend a set of unified badge definitions as follows. An article may be issued combinations (or all) of these badges at different points in time.

2.1 Open Research Objects (ORO)

This badge signals that author-created digital objects used in the research (including data and code) are permanently archived in a public repository that assigns a global identifier and guarantees persistence, and are made available via standard open licenses that maximize artifact availability.

If all relevant research objects are made available, the badge is designated by a modifier, e.g., ORO-A. This badge signals that the research publication is reproducible (as described in the NASEM Report).

Notes:

1. This is akin to author-supplied supplemental materials, shared under a standard public license such as an Open Science Initiative (OSI)–approved license for software or a Creative Commons license or public domain dedication for data and other materials.
2. This definition corresponds to the Association for Computing Machinery (ACM) “Artifacts Available” badge, and to the combined Center for Open Science (COS) “Open Data” and “Open Materials” (pertaining to digital objects) badges. (See Appendix A.)
3. The determination of what objects are “relevant” to a research publication is in the hands of the editorial board or leadership members of the community, in addition to the authors themselves.
4. For physical objects relevant to the research, the metadata about the object should be made available.

2.2 Research Objects Reviewed (ROR)

This badge signals that all relevant author-created digital objects used in the research (including data and code) were reviewed according to the criteria provided by the badge issuer. The badge metadata should link to the award criteria.

Notes:

1. A publication may be awarded the ROR badge while not being eligible for the ORO badge, and vice-versa.
2. The criteria for review of the research objects (e.g., code) need to be determined by the editorial boards, community leaders, and other stakeholders. Some efforts are underway to develop standard criteria for code review. An example set of criteria is that of the *Journal of Open Source Software* (https://joss.readthedocs.io/en/latest/review_criteria.html).
3. This badge corresponds to the ACM “Artifacts Evaluated” badge, while the Institute of Electrical and Electronics Engineers (IEEE) has used a “Code Reviewed” badge (see Appendix A).
4. Badge issuers may signal different levels of review through qualifiers identified with the badge. Examples include the Functional and Reusable levels in ACM’s “Artifacts Evaluated” badge, or criteria associated with reproducibility.

NISO RP-31-2021, Reproducibility Badging and Definitions

Examples:

1. The company Code Ocean certifies that the results can be computationally reproduced. According to the *Journal of Fancy Research*, this qualifies as reviewed. Note: this could also achieve the Results Reproduced modifier to the Badge.
2. Objects are deemed complete by a competent third-party reviewer and/or explicit journal standards.

2.3 Results Reproduced (ROR-R)

This badge signals that an additional step was taken or facilitated by the badge issuer (e.g., publisher, trusted third-party certifier) to certify that an independent party has regenerated computational results using the author-created research objects, methods, code, and conditions of analysis.

Results Reproduced assumes that the research objects were also reviewed. For this reason, a possible distinction for this badge could be as a tag on the ROR badge: ROR-R.

This Recommended Practice has adopted the National Academies of Sciences Engineering Medicine, definition of Reproducibility: “We define reproducibility to mean computational reproducibility—obtaining consistent results using the same input data, computational steps, methods, code, and conditions of analysis.”²

2.4 Results Replicated (RER)

This badge signals that an independent study, aimed at answering the same scientific question, has obtained consistent results leading to the same findings (potentially using new artifacts or methods). The badge links to the persistent identifier for that secondary publication. This badge is awarded by the publisher of the original work that is being badged.

Notes:

1. The National Academies of Sciences, Engineering, and Medicine’s 2019 Report defines replication as obtaining consistent results across studies aimed at answering the same scientific question, each of which has obtained its own data.
2. Partially replicable findings, where an independent effort has been made to regenerate the findings but has not succeeded, should be made visible in some way in the scholarly record, but we don’t recommend a badge in this instance.
3. A replication study is published separately, linking to the original study via citation. Best practice for journals is to accept replication studies for publication as a separate article type.

² Ibid.

Section 3: Badge Characteristics

3.1 Placement and Discovery

We recommend that badges be visible within view of the title and abstract of the article, on its landing page, and not solely on the article PDF. Wherever badges appear (on an article's landing page, PDF, etc.), they should respond to user mouse-click by displaying the metadata in user-friendly format, providing active links to associated research objects or review criteria.

We recommend that publishers implement badge discovery capabilities, allowing search for articles by badge type, according to this taxonomy.

3.2 Badge Metadata

Badge metadata should be stored in a machine-readable format and available via hyperlink from the issued badge. Recommended minimum fields to include in the badge include:

- Version of the schema or specification
- Issuing organization
- Badge type
- Badge definition
- Paper DOI
- Issuing date
- References (linked DOIs to artifacts)
- Review criteria URI (for the ROR badge)
- Optional: validation hash or cryptographic key

We don't include a badge identifier because each badge is uniquely associated with the article it was awarded to. The badge metadata could be included as part of the Crossref deposit of the article.

We also don't include items that belong to the metadata of the associated research objects themselves, such as data citation, software citation,³ license information, programming language, etc. Nevertheless, it's important to note that these research objects should contain standard and complete metadata.

There is opportunity to create interoperability by including badge metadata via the JATS and BITS XML Document Type Definitions (DTD).^{4,5}

Badge metadata and descriptive information should be accessible from the badge itself, preferably by link so a reader can click a badge to understand its meaning.

3.3 Badge Validator

It is recommended that issued badges be able to be validated via an API or public interface hosted by a central entity or publisher. For example, the badge image file itself (PNG or other) can contain in

³ E.g., CodeMeta (<https://codemeta.github.io>); Citation File Format (<https://citation-file-format.github.io>)

⁴ <https://jats.nlm.nih.gov/publishing/>

⁵ <https://jats.nlm.nih.gov/extensions/bits/>

NISO RP-31-2021, Reproducibility Badging and Definitions

the header a hash that allows verification of the badge as legitimately awarded by a given organization. A user may send the image file to a server API to receive validation.

3.4 Badge Help

It is recommended that all badges carry a link to official current definitions of that badge.

3.5 Badge Design

While badge design was not considered by this group per se, badges on article landing pages or PDFs should be recognizable by readers. As of the publication of this Recommended Practice, badge icons are under design. Recognizing that publishers may be constrained by platform design requirements, the Working Group's goal is to develop icons representing each level of award, which can be incorporated into a publisher-specific outer badge design.

3.6 Badge Revocation

For a variety of reasons, it should be possible to revoke a badge. A revoked badge should not disappear but be replaced with information regarding the revocation and why (in the manner of a retraction).

Section 4: Future Work

After initial release of the Recommended Practice, we propose that NISO organize a Standing Committee for the purpose of recommending implementation practices, including but not limited to badge design, badge metadata, and badge validation.

Appendix A

Currently Used Badges and Badge Hierarchies

A.1 ACM

<https://www.acm.org/publications/policies/artifact-review-badging>



Artifacts Available: Author-created artifacts relevant to this paper have been placed in a publicly accessible archival repository. A DOI or link to this repository, along with a unique identifier for the object, is provided.

Artifacts Evaluated—Functional: The artifacts associated with the research are found to be documented, consistent, complete, exercisable, and include appropriate evidence of verification and validation.

Artifacts Evaluated—Reusable: The artifacts associated with the paper are of a quality that significantly exceeds minimal functionality. That is, they have all the qualities of the Artifacts Evaluated—Functional level, but, in addition, they are very carefully documented and well-structured, to the extent that reuse and repurposing is facilitated. In particular, norms and standards of the research community for artifacts of this type are strictly adhered to.

Results Replicated: The main results of the paper have been obtained in a subsequent study by a person or team other than the authors, using, in part, artifacts provided by the author.

Results Reproduced: The main results of the paper have been independently obtained in a subsequent study by a person or team other than the authors, without the use of author-supplied artifacts.

A.2 Center for Open Science Badges⁶

<https://cos.io/our-services/open-science-badges/>

<https://osf.io/tvyxz/wiki/1.%20View%20the%20Badges/>



Open Data: awarded when digitally-shareable data necessary to reproduce the reported results are publicly available.

Open Materials: earned by making publicly available the components of the research methodology needed to reproduce the reported procedure and analysis.

Preregistered: earned for having a preregistered design.

Preregistered+Analysis: earned for having a preregistered research design (described above) and an analysis plan for the research and reporting results according to that plan.

The Center for Open Science (COS) has also produced the Transparency and Openness Promotion (TOP) Guidelines and, although they are not explicitly badges, they roughly align with the current set of COS badges. See <https://cos.io/top/> and the standards definitions at <https://osf.io/2cz65/>.

A.3 IEEE

<https://www.computer.org/csdl/journal/td/write-for-us/15085>



Code Available: The code, including any associated data and documentation, provided by the authors is reasonable and complete and can potentially be used to support reproducibility of the published results.⁷

⁶ The COS badge hierarchy does not address code/software directly, but one may assume that it is included in the “Open Materials” badge.

⁷ The IEEE “Code Available” badge does not dictate explicitly that the code be permanently archived with a global identifier.

NISO RP-31-2021, Reproducibility Badging and Definitions

Code Reviewed: The code, including any associated data and documentation, provided by the authors is reasonable and complete, runs to produce the outputs described, and can support reproducibility of the published results.

Datasets Available: Datasets provided by the author are made available by the author.

Datasets Reviewed: Datasets provided by the author have been reviewed and can support reproducibility of published results.

A.4 Springer Nature



A.4.1 Badge for Open Data

Springer Nature is running a pilot in the journal *BMC Microbiology* to evaluate if awarding open data badges affects data-sharing behaviors by authors and increases reader engagement and perceptions of article quality/reproducibility, and to aid in understanding the value of digital badges more widely. The badge is based on internal evaluation and criteria listed below, and is evaluated by the in-house Research Data Services team.

Criteria for open data badge:

- A data availability statement is included with the manuscript, stating how the data can be accessed
- Datasets (or part of the datasets) are deposited in a public repository
- DOI, accession number, or another persistent identifier is supplied for the datasets
- The datasets provided are checked and confirmed as relevant to the related paper

More details of this initiative are included at the Springer Nature blog

(<https://researchdata.springernature.com/users/182454-rebecca-pearce/posts/39872-springer-nature-launches-open-data-badges>) and at badgr

(https://badgr.io/public/assertions/CbHhR_WYSjuL1CZflJ3fSA).

A.4.2 Code Peer Review and Publication

Springer Nature journals request that custom code that is central to the paper be submitted during peer review for evaluation by the reviewers. They follow specific guidelines for code submissions⁸ and request that authors complete a checklist when they compile and submit the code. The code is then provided to the reviewers, who are asked to check it (verify it is well documented and install and run

⁸ Springer Nature. *Nature Research*, “Guidelines for authors submitting code & software.”

(<https://www.nature.com/documents/GuidelinesCodePublication.pdf>)

NISO RP-31-2021, Reproducibility Badging and Definitions

it to verify that it is functional). Upon publication, details about how readers can access the code are provided in a Code Availability statement in the paper.

Details of this practice are reported in a *Nature* editorial (<http://dx.doi.org/10.1038/d41586-018-02741-4>).

This initiative does not yet include a digital badge for code verification and/or accessibility, but Springer Nature is interested in implementing such badges following community practices.

In addition, several Nature journals are running trials to evaluate the use of software container platforms to improve code peer review and accessibility in the published paper. Details of this trial, which is ongoing with Code Ocean, were reported in *Of Schemes and Memes*, a Nature blog, in August 2018 (<http://blogs.nature.com/ofschemesandmemes/2018/08/01/nature-research-journals-trial-new-tools-to-enhance-code-peer-review-and-publication>).

A.5 Elsevier

Elsevier currently places Open Science Framework badges on articles in *Journal of Experimental Social Psychology*, *Cortex*, and *Evolution and Human Behavior*. The badges are for recognition of Open Data, Open Materials and Pre-Registration. In order to implement this recognition, questions were added to the submission process for each journal, asking the author if they would like to apply for the badges and to verify that they qualify. Badges are entirely optional for authors. Editors are then asked to do a brief check on this information on acceptance of the article.

The journals include information in the Guide for Authors (see the example below) about badges and also provide information to editors for handling papers with badges. The journals use the OSF-defined method of “Disclosure” to verify the badges:

“Disclosure requires authors to provide public statements affirming achievement of badge criteria. The certifying organization evaluates the disclosure before issuing the badge but does not perform more than a cursory evaluation of the data, materials, or registration. Such a review might include: confirming that the provided link leads to the data, materials, or registration on a public, open access repository, and that the linked materials are related to the report. Authors follow criteria for each badge and complete disclosure items that will be made publicly available. Authors are accountable to the community for disclosure accuracy.”⁹

Currently, the badge(s) designed by the Open Science Framework are only included on the published PDF of the article, as shown in Figure 1, below.

⁹ <https://osf.io/tvyxz/wiki/2.%20Awarding%20Badges/>



Figure 1: Elsevier Badges¹⁰

At present, the evaluation process for these pilot journals is manual. Should there be an opportunity to automate parts of the process in the future, it could be expanded to many more journals.

Example of the relevant section in the Guide for Authors (from *Journal of Experimental Social Psychology*):

Open Practice Badges

Journal of Experimental Social Psychology recognizes the value of researchers sharing their results in ways that allow others to reproduce their findings and reuse their methods and data in new research. With the increasing volume of data and computational complexity of methods, in many cases it is not possible to communicate many important details of a research project within the limitations of a journal article. This can make it difficult to assess the credibility of research results, and to efficiently reuse and extend them. To address this challenge, the editors of the *Journal of Experimental Social Psychology* encourage authors to make the data and methods associated with their journal article publicly available in publicly accessible online repositories.

In recognition of authors' efforts to make their research output more accessible, authors have the option to request that manuscripts are published with up to three badges recognizing open scientific practices. The three badges, created by the Open Science Framework (OSF), are:

- Open Data
- Open Materials
- Pre-registered

To request any (or all) of these badges, authors should select the appropriate badges in the submission form, when submitting their paper to the journal. Badges are assigned following the Disclosure method (<https://osf.io/tyyxz/wiki/2.%20Awarding%20Badges/>), overseen by the handling editor of their manuscript.

¹⁰ <https://www.sciencedirect.com/science/article/abs/pii/S0022103116301354>

NISO RP-31-2021, Reproducibility Badging and Definitions

Authors who choose badges must include an “Open Practices” section in their manuscript before the references. This should include links to any open data, materials for pre-registration.

Articles will be published with the badges appearing next to the title of the article in the PDF. An example can be found here:

<https://www.sciencedirect.com/science/article/abs/pii/S0022103116301354>.

The badges are optional, and authors can continue to publish their work without any badges, if they so wish.

A.6 Wiley

Wiley journals are beginning to adopt badges that recognize various “open” practices. This is currently a ground-up, opt-in initiative championed by members of Wiley’s Integrity and Ethics Strategy Board (convened by Chris Graf, Director of Research Integrity and Publishing Ethics at Wiley, and co-chair of the Committee on Publication Ethics) alongside editorial and production colleagues.

The text below was added to author guidelines for participating Wiley journals, depending on the types of badges offered. Once an article is published in a participating journal, an Open Research section is displayed on the Wiley Online Library article page. This section is in front of the paywall and contains the Open Research badges and data availability statements, if supplied by authors at submission; the text below the badges includes the author-provided links to their materials.

Author guidelines text:

“Recognizing the importance of research transparency and data sharing to cumulative research, <Journal Name> encourages the following Open Research practices.

Sharing of data, materials, research instruments and their accessibility. <Journal Name> encourages authors to share the data, materials, research instruments, and other artifacts supporting the results in their study by archiving them in an appropriate public repository. Qualifying public, open-access repositories are committed to preserving data, materials, and/or registered analysis plans and keeping them publicly accessible via the web into perpetuity. Examples include the Open Science Framework (OSF) and the various Dataverse networks. Hundreds of other qualifying data/materials repositories are listed at the Registry of Research Data Repositories (<http://www.re3data.org>). Personal websites and most departmental websites do not qualify as repositories.

Open Research Badges. In partnership with the non-profit Center for Open Science (COS), <Journal Name> offers all submitting authors access to the following three Open Research Badges— Open Materials, Open Data, and Preregistered Research Designs. We also award all qualifying authors Open Research Badges recognizing their contributions to the Open Research movement. The Open Research practices and associated award badges, as implemented by the Center for Open Science and supported by <Journal Name>, are the following:

The Open Materials Badge recognizes researchers who share their research instruments and materials in a publicly accessible format, providing sufficient information for researchers to reproduce procedures and analyses of published research studies. In the field of <Field Name> research, a qualifying public, open-access database of research instruments and materials is <Name of Database> (URL).

NISO RP-31-2021, Reproducibility Badging and Definitions

The Open Data Badge recognizes researchers who make their data publicly available, providing sufficient description of the data to allow researchers to reproduce research findings of published research studies. An example of a qualifying public, open-access database for data sharing is the Open Science Framework repository. Numerous other data-sharing repositories are available through various Dataverse networks (e.g., <http://dataverse.org>) and hundreds of other databases available through the Registry of Research Data Repositories (<http://www.re3data.org>). There are, of course, circumstances in which it is not possible or advisable to share data publicly. For example, there are cases in which sharing participant data could violate confidentiality. In these cases, the authors may provide an explanation of such circumstances in the Alternative Note section of the disclosure form. The information the authors provide will be included in the article's Open Research note.

The Preregistered Badge recognizes researchers who preregister their research plans (research design and data analysis plan) prior to engaging in research and who closely follow the preregistered design and data analysis plan in reporting their research findings. The criteria for earning this badge thus include a date-stamped registration of a study plan in such venues as the Open Science Framework (<https://osf.io>) or Clinical Trials (<https://clinicaltrials.gov>) and a close correspondence between the preregistered and the implemented data collection and analysis plans.

Authors will have an opportunity at the time of manuscript submission and at the time of acceptance to inform themselves of this initiative and to determine whether they wish to participate. Applying and qualifying for Open Research Badges is not a requirement for publishing with <Journal Name>, but these badges are further incentive for authors to participate in the Open Research movement and thus to increase the visibility and transparency of their research.

More information about the Open Research Badges is available from the Open Science Framework wiki.”

A.7 Other Journal Efforts

A.7.1 *Biostatistics*

Articles are kitemarked with “R” if the journal’s reproducibility editor was able to reproduce the reported results, “C” if code was made available, and “D” if data was made available. A kitemark of “R” implies kitemarks of “C” and “D.” See also “Reproducible research and *Biostatistics*” (2009) (<https://www.ncbi.nlm.nih.gov/pubmed/19535325>) and “Badges for sharing data and code at *Biostatistics*: an observational study” (2018) (<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5843843/>).

A.7.2 *Journal of the American Statistical Association* – Application and Case Studies

While the efforts of this journal do not extend strictly to badging, they require a two-page description of artifacts and workflow information required to computationally reproduce the results in the publication (an Author Contributions Checklist). See “Reproducible Research in JASA” (2016) (<https://magazine.amstat.org/blog/2016/07/01/jasa-reproducible16/>).

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