

# Reproducibility and Replicability in the Liberal Arts

## Highlights from an Alliance to Advance Liberal Arts Colleges Workshop at Middlebury College, July 14-17 2024

### Reproducibility and the Pursuit of Knowledge

*Reproducible*: the research procedures can be repeated in the same context with the same data and produce the same or similar results.

*Replicable*: the research procedures can be repeated in new contexts with new data and produce similar results.

*Valid*: the research measures what it intends to and its claims are well-founded and consistent with the procedures, data and analysis.

|                   | Same Data    | Different Data |
|-------------------|--------------|----------------|
| Same Methods      | Reproduction | Replication    |
| Different Methods | Reanalysis   | Extension      |

Christensen, Freese and Miguel (2019)

We *reproduce* and *reanalyze* prior studies in order to *internally validate* them.

We *replicate* prior studies in order to *externally validate* them.

In an *open science* framework, reproducible and replicable studies can be *extended* with new data and approaches to accelerate discovery.



In *higher education*, our institutional missions are to develop the *creative agency*, *ethics*, and *critical information literacy* of our students.

In the *2023 Year of Open Science*, U.S. federal agencies redoubled their promotion of reproducible, accessible and inclusive science and scientific data.

These two aims are **complementary**.



By teaching *reproducibility* starting at the undergraduate level, we can *improve student learning*, and prepare them to navigate a complex world with an abundance of *misinformation* built at least in part on *questionable research practices*. Indeed, researchers often follow many paths of possible reasonable decisions in pursuit of significant findings. Successful studies are published while other results are typically relegated to the file drawer.

### Innovating with Reproducibility and Replicability (R&R) at three levels:

#### COURSES – CURRICULA – INSTITUTIONS

### Courses

**Findings:** There are many easy entry points to introduce Reproducibility and Replicability in courses, and professors may proceed incrementally. Be honest about challenges learning to work reproducibly and emphasize the benefits. Provide students with conceptual and analytical tools to navigate the complexity and uncertainty inherent to research, and to evaluate a range of possible solutions to any given research question. Reinforce learning through cognitive self-reflection and community engagement or project-based learning.

#### Examples:

- At **Haverford College**, Richard Ball teaches students to organize their research projects with a reproducible protocol.
- At **Middlebury College** and **UCSB**, Joseph Holler and Peter Kedron teach students how to reproduce prior studies.
- Students also learn to write a pre-analysis research plan prior to analyzing data.
- At **Smith College**, Scott Lacombe teaches reproducibility by rotating research projects through small groups during the course. One groups' work becomes the starting point for the next.
- At **Mount Holyoke College**, Laurie Tupper teaches students to experiment with questionable research practices so that they can understand and avoid them.
- At **Denison University**, Matthew Lavin uses self- and peer-reviews of code to improve rigor and reproducibility.



### Find Us



DOI: 10.17605/OSF.IO/GZHC8  
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### Curricula

**Findings:** R&R can be introduced from the earliest levels of the curricula in preparation for reproducible research projects at advanced levels. This requires scaffolding research competencies as students progress through the curriculum.

#### Examples:

- Sarah Supp** works with the **Biological and Environmental Data Education Network** to collaborate on a **research competency model** for quantitative biological and ecological research.
- The **Dension University** Data Analytics Major integrates reproducibility at all levels of it's major requirements.
- Ben Gebre-Medhin** has developed a sequence of courses for reproducible computational text analysis at Mount Holyoke College.
- Joseph Holler** introduces reproducible workflows and geospatial metadata from the introductory level prior to advanced open spatial data science.

### Institutions of Higher Education

**Findings:** The educational missions of institutions of higher education are complementary to the principles and practices of reproducibility and replicability. Institutions can support this through funding, valuing reproducibility and replicability for review promotion, interdisciplinary hubs for training and assistantships, and community-engaged scholarship.

#### Examples:

- In **Wesleyan University's** Hazel Quantitative Analysis Center, Emmanuel Kaparakis coordinates reproducible data science through cohorts of summer apprenticeships and fellowships to support student development and faculty research, and quantitative tutoring.
- At the **College of Wooster**, Anne Nurse uses reproducibility to add value and rigor to community-engaged research and institutional research.
- At **Middlebury College**, the **midd.data** program sponsors small projects, leave fellowships, and a data sciences across the disciplines course.
- From **Haverford College**, Richard Ball steers Project TIER's protocol for reproducible research and training for professors.



### Authors

#### Disciplines Represented

Data Analytics, Data Science, Ecology, Economics, Environmental Studies, Geography, Government, Humanities Analytics, Latin American Studies, Library, Sociology, Statistics

#### Organizing Committee

Joseph Holler, Middlebury College  
Richard Ball, Haverford College  
Nicholas Horton, Amherst College  
Emmanuel Kaparakis, Wesleyan University  
Sarah Supp, Denison College

#### Keynote Speakers

Peter Kedron, University of California, Santa Barbara  
Anne Nurse, The College of Wooster

#### Participants

Julia Deen, Middlebury College  
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