

REPRODUCIBILITY REPORT



The ability to reproduce experiments is the bedrock of scientific knowledge. Researchers rely on replication to confirm experimental results and weed out false conclusions. Yet, this critical process in scientific research is in crisis, and researchers are struggling to reproduce significant theories and methodologies.

A survey of 415 scientists from North America, Europe, and China examined the causes of the reproducibility crisis, its effect on scientists, and which biomedical scientists are most affected.

The results from the survey were highly informative on the current state of reproducibility. It found that **two-thirds of respondents strongly agree that reproducibility is an urgent problem.** Academic scientists (72%) seem to indicate that this is urgent, compared to industry scientists (59%). (See Figure 1)

There is a clear generational divide in how scientists view reproducibility. Of those surveyed, **younger scientists found the reproducibility crisis more urgent.** This may be because younger researchers who are less established may suffer greater consequences from failing to reproduce a study. Younger scientists also believe that a toxic scientific culture is driving the crisis, as well as a “publish or perish” creed. Scientists generally agreed that a bias toward publishing only positive results, insufficient emphasis on methods in publications, and inadequate research-methods training add to the crisis.

All respondents are frustrated by the time and financial resources wasted due to reproducibility, but the reputational effects of this crisis also weigh heavily on their minds. This sentiment is echoed even more so among cell line users who borrow cells from their colleagues.

Scientists who borrow cell lines and/or do not authenticate their cell lines have more replication issues. Cell line users who rely primarily on vendor-supplied cell lines report significantly fewer problems, including less disillusionment with the scientific process. That suggests one potential improvement to the reproducibility crisis is greater use of vendor-supplied cell lines.

Other solutions include improving methods disclosure in published work, publishing null results, and improving methods training.

There is also a specific call for funding agencies and journal editors to enforce requirements that may improve reproducibility.

DETAILED FINDINGS

We surveyed researchers in the biological sciences, chemistry, and medicine. 60% of our sample comes from academic and government institutions, and the rest represents both the pharma and biotech industries. Over one-third (34%) of the sample is millennials (under 39 years old), another 56% of our respondents are between the ages of 40-60, and the final 10% are above 60 years old. (See Figure 1)

Figure 1

REPRODUCIBILITY PROBLEMS—THE URGENCY

Answered by 415 respondents.

Q: To what extent do you agree that reproducibility is an urgent problem in science, in general?

Total (n=415)
OF ALL RESPONDENTS WHO INDICATED A 6 OR 7 ON THE SCALE

65%

Breakdown

Region

North America (n=211)	68%
Europe (n=107)	67%
APAC/Other (n=45)	44%

Institution Type

Academic (n=260)	72%
Government (n=28)	57%
Industry (n=176)	59%

Age Group (yrs.)

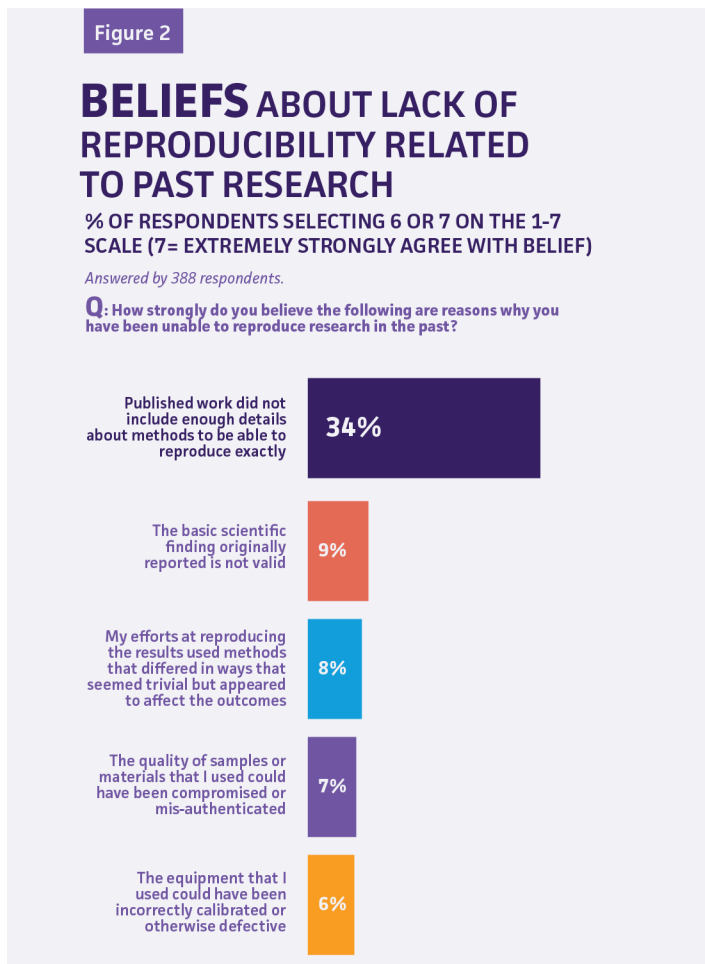
< 40 (n=144)	71%
40+ (n=271)	62%

Uses Cell Lines in Work

Cell Line Non-Users (n=50)	60%
Cell Line Users (n=341)	67%

CAUSES OF REPRODUCIBILITY PROBLEMS

Overwhelmingly, researchers who were unable to reproduce research in the past believe that the primary reason for being unable to do so is due to insufficient detail about methods. (See Figure 2)



Half of the study's respondents attribute the lack of reproducibility to the pressure to publish. Only 9% of respondents believe that carelessness is a significant cause. (See Figure 3)

IMPACT OF REPRODUCIBILITY PROBLEMS

Scientists seem to be particularly frustrated with the waste of time and resources associated with reproducibility. One-third of scientists are losing trust in colleagues and collaborators, and a quarter is disillusioned with the scientific process. Respondents also fear for their reputation (20%) or the integrity of their research materials (25%).

Some also find that they are in disagreements with editors about the meaning of results that fail to replicate. (See Figure 4) Nine out of ten scientists do not believe that granting agencies or publishers are doing an adequate job in enforcing requirements that improve reproducibility.

Figure 3

CAUSES OF REPRODUCIBILITY PROBLEMS

% OF RESPONDENTS SELECTING

Answered by 415 respondents.

Q: Which of the following causes do you believe contribute to the reproducibility problems in the scientific field?



This problem impacts the process of drug development directly. On average over three years, our survey reports that scientists lose tens of thousands of dollars (an average of US\$28,500 across regions and institutions). The proportion of loss is substantially high for both industry and academia, with industry losing US\$45,000 and academia losing US\$16,500.

SOLUTIONS TO ADDRESS REPRODUCIBILITY PROBLEMS

Researchers identified three key areas of focus for solutions:

- 1) Publications' bias toward positive results
- 2) Insufficient emphasis on methods in publications
- 3) Inadequate research methods training

Fraud is also identified as a serious cause to the lack of

Figure 4

IMPACT OF REPRODUCIBILITY PROBLEMS

% OF RESPONDENTS SELECTING *Answered by 415 respondents.* Q: How have reproducibility problems in science affected your work?



Figure 5

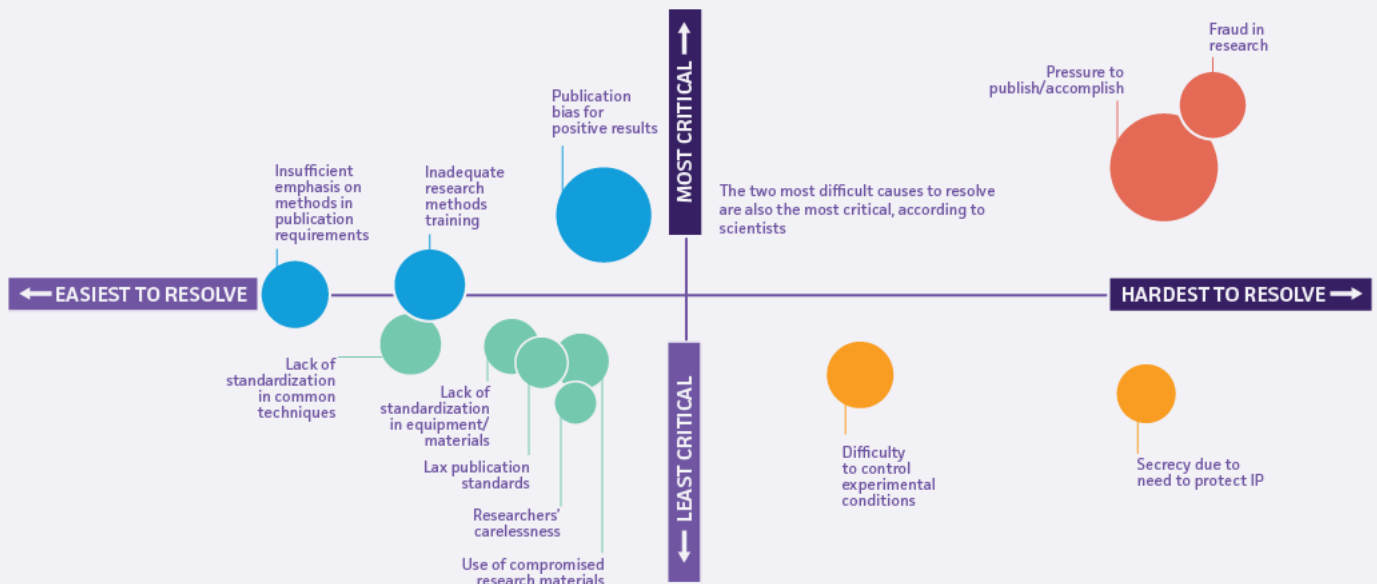
CAUSES OF REPRODUCIBILITY PROBLEMS

MAPPING DIFFICULTY & CRITICALITY OF RESOLVING

Answered by 415 respondents. Size of circles indicates what % of scientists agree it's a cause of reproducibility problems (larger = more scientists agree)

Q: Which of the following causes do you believe contribute to the reproducibility problems in your scientific field?

Q: Which of these causes do you find to be the easiest to solve or address right now? Which are the most difficult? Q: Which of these causes do you find to be the most critical to resolve?



reproducibility but is found to be far more difficult to resolve. (See Figure 5)

The most fundamental and simplest solutions involve publication requirements.

These Solutions Are:

- More detailed methods, protocols, data, materials, software, and other tools in published research (35%)

- Better training on methods/study design/analysis (24%)
- Cultural shifts lauding accuracy over speed (23%)
- Publishing null or negative results, together with positive results (22%)

(See Figure 6)

The survey data also suggests that being proactive is effective. Scientists troubleshoot issues when their initial reproduction effort

Figure 6

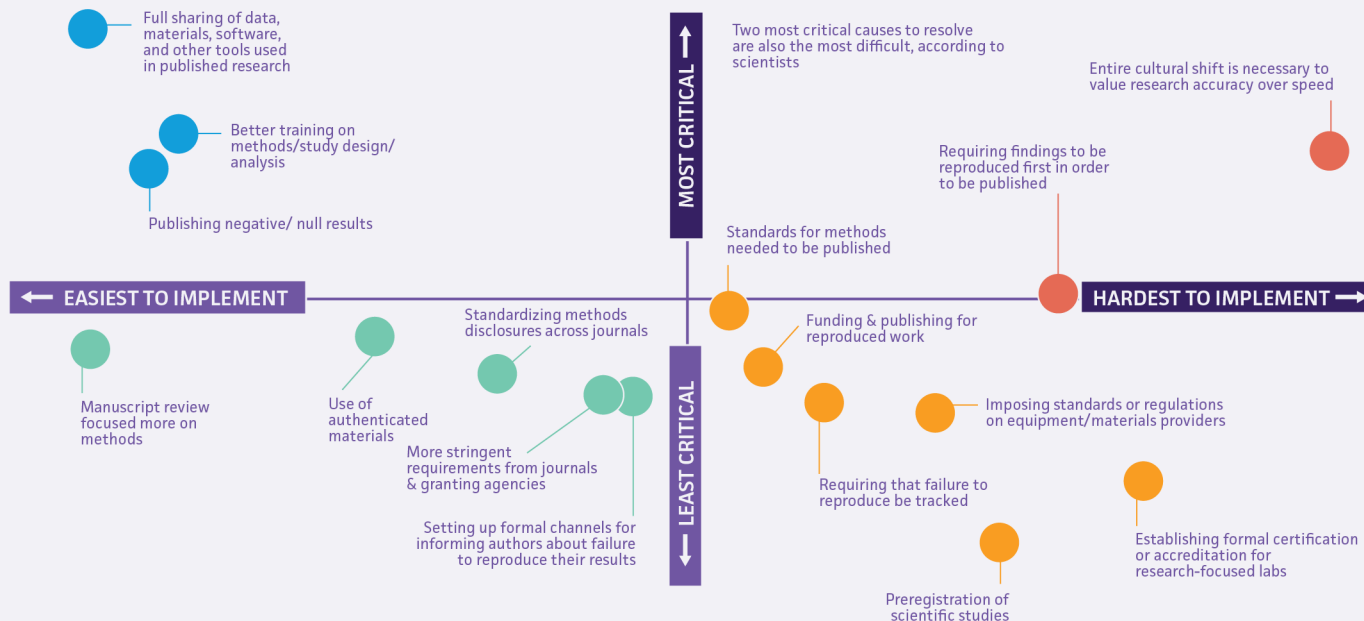
SOLUTIONS TO REPRODUCIBILITY PROBLEMS

MAPPING DIFFICULTY & CRITICALITY OF SOLUTIONS

Answered by 415 respondents.

Q: Which of these solutions do you find to be the most critical to implement to ensure improvement in reproducibility in science?

Q: Which of these solutions do you find to be the easiest to implement right now? Which three are the most difficult?



fails. Over half of respondents (54%) run the same experiment again, 42% consult with other experts, 20% inform the research’s authors about the inability to reproduce, 9% of respondents attempt to publish information about the failure to reproduce, and 6% inform journal editors of the original article about the inability to reproduce.

Scientists believe that researchers (24%), journals (20%), and funding agencies (19%) have the most influence over the industry (6%). Nearly half of the respondents suggest that educational institutions should ensure adequate training measures are in place to enforce reproducibility.

The Sentiment of the Problem for the Younger Generation

The perceived urgency of the problem varies among age groups, where the highest is among millennial researchers and the lowest among older researchers. (See Figure 8 in the Appendix)

There are strong generational differences in addressing the problem of reproducibility. Younger scientists argue that there needs to be a cultural shift that values accuracy over speed, while the older group strongly believes that better training is required. (See Figure 10 in Appendix)

All of the respondents attribute the crisis in part to a highly competitive scientific environment and the “publish or perish” culture. Nearly six in ten respondents believe that the pressure to publish and publication bias toward positive results is a leading contributor to reproducibility issues today. According to the data, these factors are also establishing a sense of disillusionment in the scientific process in this younger generation.

Behaviors of Researchers Who Use Cell Lines

Our survey reveals those scientists who don’t borrow cell lines, and/or those who authenticate their cell lines, report more success reproducing the research. **But nine out of ten respondents continue to obtain cell lines from colleagues or other labs.** And our survey respondents claim to obtain cell lines from known-biological material suppliers only one third of the time. (See Figure 9 in Appendix) Scientists using cell lines in their work report that they re-authenticate cell lines in only about 29% of cases.

Scientists who use cell lines appear more concerned about the reputational aspects of reproducibility (in the 20% of respondents who use cell lines vs. the 8% who do not use them). They also fear for their reputations and report losing trust in colleagues and collaborators (35% of respondents who use cell lines vs. the 16% who do not use them).

Cell line users who rely primarily on vendor-supplied cell lines report significantly fewer problems and less disillusionment with the scientific process (only 13% of respondents vs. 39% who don't use vendor-supplied cell lines at all). (See Figure 7)

Those who borrow cell lines from colleagues are less likely to believe that reproducibility problems are due to design considerations (50% of those respondents vs. 66% of those who do not borrow cell lines), such as lack of proper controls (18% vs. 32%) or lack of standard materials (12% vs. 27%) or a lack of standardization in equipment or materials (only 12%). These scientists may be unable to recognize that lack of re-authentication or other design problems may be contributing to their reproducibility problems.

CONCLUSION

For the scientific community, this survey not only sheds light on the very problems at the root of the reproducibility crisis, but also nods

to viable solutions and behaviors that scientists across disciplines, generations, and countries can support. As Figure 5 shows, there are critical yet easy solutions to resolve the reproducibility problem, like providing more information on methods and training, as well as publishing null results. Researchers have the means to control these activities themselves.

Besides the fundamental requirements, there is a strong call to action for researchers to turn around the crisis by actively striving toward a cultural shift that banishes toxic behavior and strives to end the "publish or perish" mentality so rising scientists can validate their experiments.

The future of reproducibility matters and this survey puts the power in the minds and the hands of scientists across the world.

Figure 7

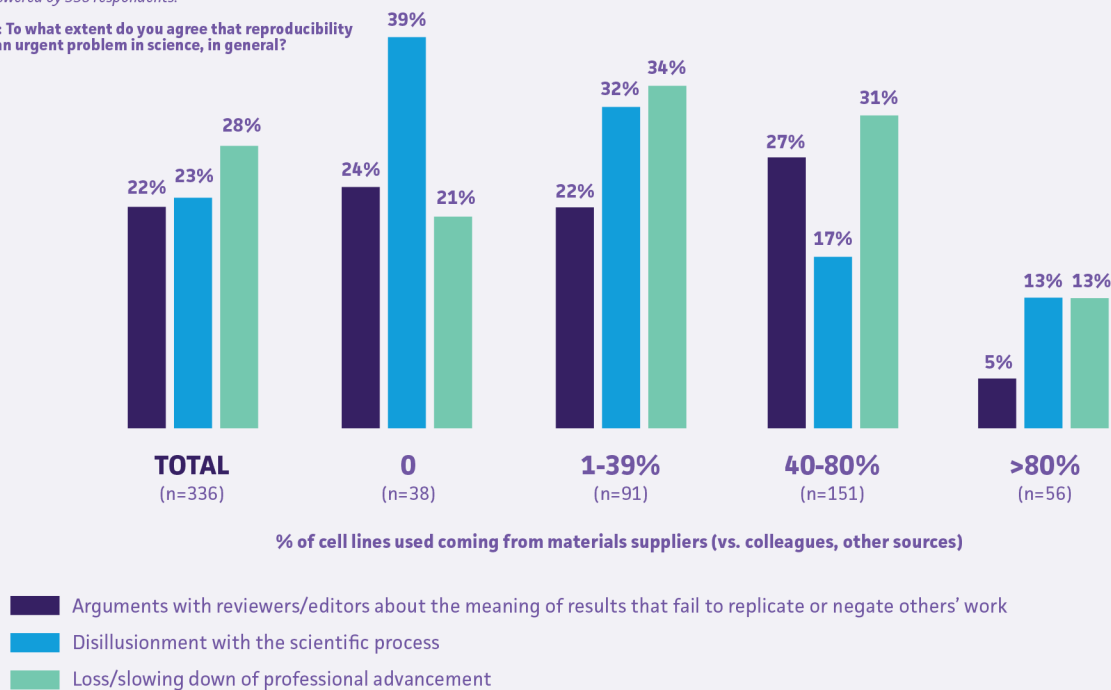
EFFECTS OF REPRODUCIBILITY PROBLEMS BY SOURCE OF CELL LINES

% OF RESPONDENTS USING CELL LINES

% OF RESPONDENTS SELECTING 6 OR 7 ON THE 1-7 SCALE (7= EXTREMELY STRONGLY AGREE WITH BELIEF)

Answered by 336 respondents.

Q: To what extent do you agree that reproducibility is an urgent problem in science, in general?



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APPENDIX

Figure 8

URGENCY OF REPRODUCIBILITY PROBLEMS BY AGE GROUPS

% OF RESPONDENTS SELECTING 6 OR 7 ON THE 1-7 SCALE (7= EXTREMELY STRONGLY AGREE WITH BELIEF)

Answered by 415 respondents.

Q: To what extent do you agree that reproducibility is an urgent problem in science, in general?

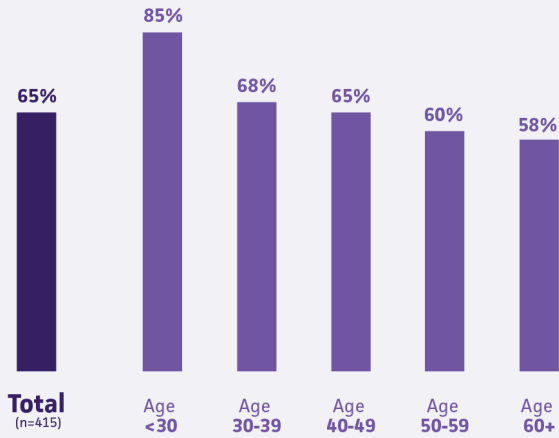


Figure 9

SOURCES OF CELL LINES

% OF RESEARCH FROM THE FOLLOWING SOURCES

Answered by 336 respondents.

Q: In what percentage of your research were cell lines that you used from the following sources?

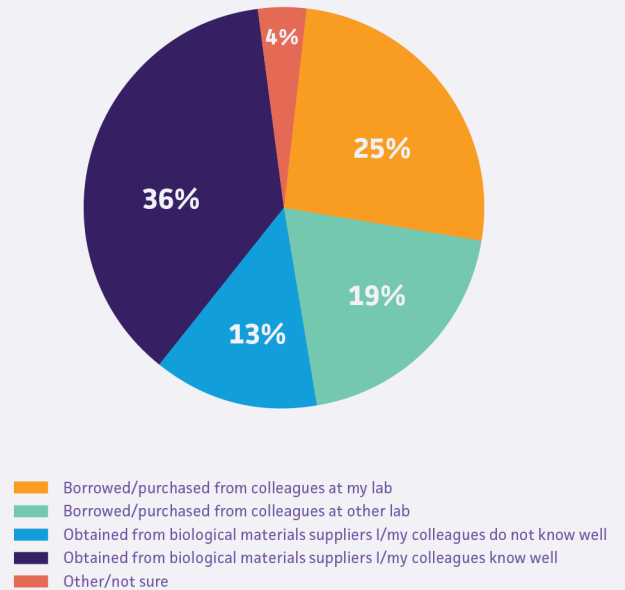
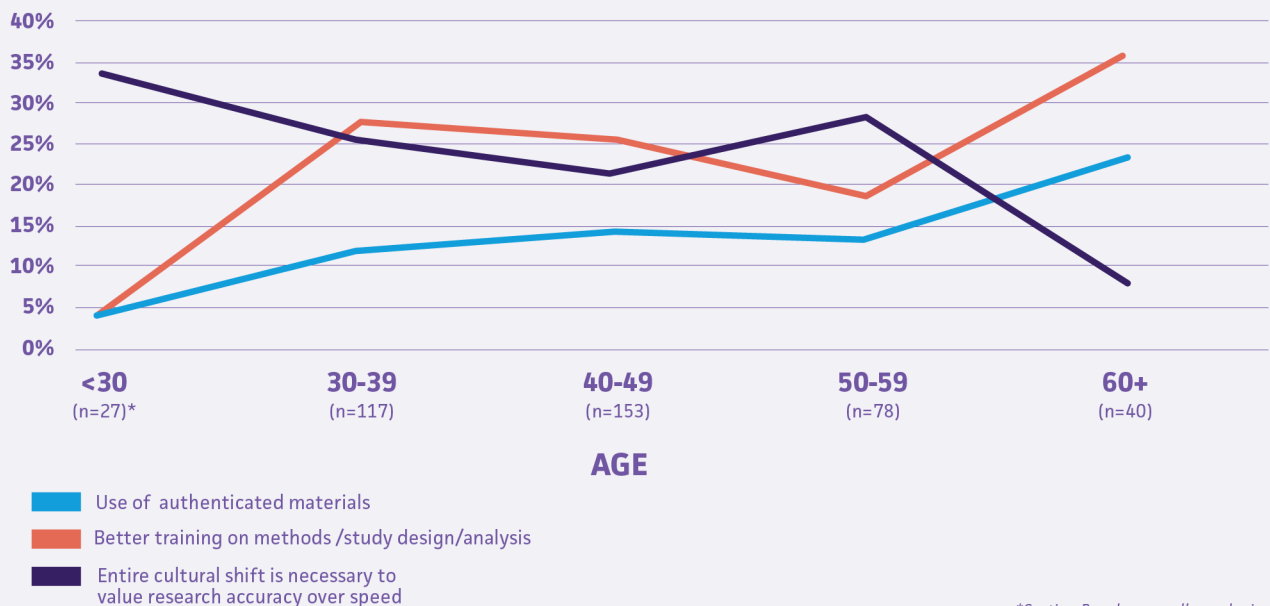


Figure 10

MOST CRITICAL SOLUTIONS TO REPRODUCIBILITY PROBLEMS

% OF RESPONDENTS, BY AGE GROUPS

Answered by 415 respondents. Q: How have reproducibility problems in science affected your work?



*Caution: Based on a small sample size