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Reproducibility, Replicability, and Transparency in Research: What 452 Professors Think in Universities across the USA and India

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In the past decade, open science and science of science communities have initiated innovative efforts to address concerns about the reproducibility and replicability of published scientific research. In some respects, these efforts have been successful, yet there are still many pockets of researchers with little to no familiarity with these concerns, subsequent responses, or best practices for engaging in reproducible, replicable, and reliable scholarship. In this study, we surveyed 452 professors from universities across the USA and India to understand perspectives on scientific processes in a Western country and in a country from the Global South. We explore similarities and differences in attitudes towards reproducibility and open science practices among social science and engineering researchers in these culturally distinct countries. Our analysis facilitates the identification of key intervention points and provides recommendations for the global implementation of open science practices. Our findings reveal both national and disciplinary gaps in attention to reproducibility and replicability, aggravated by incentive misalignment and resource constraints. We suggest that solutions addressing scientific integrity should be culturally-centered, where definitions of culture should include both regional and domain-specific elements.

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1. Introduction

Reproducibility and replicability have gained significant attention in scientific discourse, deeply intertwined with questions about scientific processes, policies, and incentives [56, 26, 24, 58, 34]. We adopt definitions for Reproducibility and Replicability from [34, 41, 44]. *Reproducibility* refers to computational repeatability – obtaining consistent computational results using the same data, methods, code, and conditions of analysis; *replicability* means obtaining consistent results on a new dataset using similar methods. Each of these concepts captures some subset of qualities we might consider important for contextualizing confidence in a given claim or finding. The two terms been frequently mentioned together or even used interchangeably due to their close relatedness [31, 45].

Attention to reproducibility and replicability have intensified over the past decade thanks to a number of high-profile findings. In 2016, a survey published in Nature reported that more than 70% of researchers have attempted and failed to reproduce other scientists' experiments, and more than half have been unable to reproduce their own[4]. The same paper reported that 52% of surveyed researchers believe that there is a significant 'crisis' of reproducibility in science. Initially centered around the social and behavioral sciences, concerns about reproducibility and replicability now span almost all empirical disciplines [4] including artificial intelligence and machine learning [64, 20]. Scholars have pointed to a number of reasons for the crisis. These include questionable research practices, such as p-hacking and HARKing (hypothesizing after results are known) [15], selective analysis, selective reporting [51], and lack of transparency [32]. Other contributors to low replication rates include misaligned incentives and failures of peer review [3, 36, 54]. These factors diminish researchers' motivation to conduct quality checks, prompting them to prioritize publishability over reliability.

The open science and science of science communities have responded with innovative initiatives aimed at shoring up the entire research workflow, from conception and study design to data collection and analysis, through to publishing [40, 42, 43]. These efforts have already had important individual and institutional impacts, many of which have been well-documented [59, 27]. For example, the Special Interest Group on Computer-Human Interaction (SIGCHI) now recommends providing supplementary materials for ACM publications to enhance replicability [12] and some universities have begun to reward researchers whose work aligns with standards of open science and transparency [55].

Despite these promising advances, however, conversations around reproducibility and replicability have predominantly reflected the voices of researchers in the global North and West [28, 11, 63, 14]. This is concerning for a number of reasons, most primarily because issues of scientific integrity and scientific process are deeply social and contextual. Our work takes an initial step toward the inclusion of cultural perspectives through a comparative study of researchers in the USA and India to highlight the differences. India currently ranks third in research output generation worldwide, following China and the USA [5].

We conduct an exploratory survey-based study involving research faculty from universities in the USA and India. We aimed to gather the perspectives of scientists across different research disciplines within social science and engineering. The survey asked participants about their familiarity with the reproducibility crisis, open science, their experiences while replicating other studies, and the factors they believe contribute to this high or low-confidence research. Additionally, we asked participants to share the institutional and practical challenges they faced during their research. We reached out to over 8400 research faculty members and received a total of 452 responses. The following research questions drive this work:

- **RQ1**: What are the awareness, concerns, signals of credibility, and experiences around reproducibility, replicability, and open science practices in the USA and India between social science and engineering researchers?

- **RQ2**: How do institutional challenges and opportunities differ between these two countries concerning reproducibility and replicability? Is there any critical difference between social science and engineering researchers?

Our findings contribute to the global conversation on scientific integrity, underscoring the need to understand challenges and solutions in a cultural context. It supports the presence of community bias and compound inequalities in the education society which has not been appreciated fully by the open science community. Also, the result suggests that there is a bias toward the author's reputation and therefore how this can be mitigated during the open peer review is not clear. On the other hand, there is a huge demand for reproducibility and open science courses for the undergraduate curriculum by the respondents which is necessary to implement. Whereas most of the universities don't have these courses for graduate students as well. Finally based on the findings we have provided recommendations for the educational stakeholders and the open science community to understand the potential movements needed to be taken.

2. Related Work

This section represents the study within the context of existing literature. It provides background information on the reproducibility crisis and open research practices.

(a) The Reproducibility 'Crisis'

In recent years, several scientific disciplines, including psychology, medicine, cancer biology, economics, and machine learning, have experienced challenges with reproduction and replication of the existing findings [57]. Large-scale replication projects in psychology [10], economics [8], sociology [9], biology [13] and beyond have turned up disappointing results. These projects have garnered significant attention following observations that outcomes from many reputable scientific journals are difficult to reproduce, and many of the findings are not replicable either. In 2015, a research experiment was performed which is called Reproducibility Project: Psychology (RPP) [10] where the replication rate achieved by the researchers was 37.5%. Another large-scale experiment was done in the field of economics which is known as the Experimental Economics Replications Project (EERP) [8], where they found 11 findings were correct out of 18. The other two projects are ML Labs 2 [21] and Social Science Replication Project (SSRP) [9]. The rate of successful replication in these large-scale projects ranges between 36% percent and 78% percent and increased the debate on the crisis of confidence in published research work. Transparency and reproducibility are closely intertwined concepts in scientific research, and their relationship is fundamental to the integrity and progress of science. Transparency lays the groundwork for reproducibility, while reproducibility refers to the ability to obtain consistent results [16, 25]. With the recent advancement in technology which involves artificial intelligence and machine learning, and the increasing amount of research papers made people think about the crisis more, it has been found that AI and machine learning research has not escaped from this crisis[**gundersen2023improving**, 19]. All these concerns have a direct impact on public trust in science and productivity.

(b) Open Science

Open Science represents a broad movement aimed at making scientific research and its dissemination accessible to all levels of society, amateur or professional. The goal of Open Science is to enhance transparency, reproducibility, and public engagement in scientific research, thereby accelerating innovation and ensuring a more efficient and effective use of research findings for the greater good. Concerns about reproducibility and replicability are closely related to principles and practices of open science [30, 7, 1, 48]. The UNESCO Recommendation on Open Science defines open science, sweepingly, as "an inclusive construct that combines various movements and practices aiming to make multilingual scientific knowledge openly available, accessible and reusable for everyone, to increase scientific collaborations and sharing of information for the benefits of science and society, and to open the processes of scientific knowledge creation, evaluation, and communication to societal actors beyond the traditional scientific community. It comprises all scientific disciplines and aspects of scholarly practices, including basic and applied sciences, natural and social sciences, and the humanities, and it builds on the following key pillars: open scientific knowledge, open science infrastructures, science communication, open engagement of societal actors and open dialogue with other knowledge systems" [62]. In this context, researchers have begun to scaffold clear and specific practices that align with open science; chief amongst them is the notion of transparency. Transparent research practices include sharing data and code, comprehensive detailing of methodologies, and clear identification of theoretical foundations [40, 22]. Researchers have found that making code available has a positive correlation with increased citations [47]. The specific character of best practices, of course, varies across disciplines. It also encourages open peer review where the reviewers' identities are known to the authors, and/or the review reports are published alongside the articles. The reviewers play a major role when it comes to the implementation of these open science practices[**morey2016peer**].

(c) Open Science Practices - Not Fully Successful

Open science practices still have not been implemented successfully, despite their potential benefits for enhancing transparency, reproducibility, and replicability. For instance, Gunzer et al. [17] analyzed 83 articles on AI neuroimaging models published between 2000 and 2020, finding that only 10.15% included open-source code. Similarly, a recent survey from the ACM Conference on Learning Scale revealed that none of the 93 papers from 2021-2022 had a corresponding preregistration, and only one used a dataset that was made openly available [18]. In a study examining open science norms in clinical psychology, while 98% of 100 papers sampled between 2000 and 2020 had some data available, only one provided an analysis script [25]. It is very clear that data sharing is a common practice. Selective reporting and insufficient description of methodology also hinder transparency [3, 44]. In machine learning and AI, transparency is central to discussions about ethical engagement with emerging technologies [2, 46]. Predominantly, transparency has been considered a precursor to the explainability of algorithms and methodology. Transparency and Open science are not only about computational methods rather it is important for any scientific studies. Researchers have also highlighted how the replication crisis impacts fields like Human-Computer Interaction (HCI)[**<empty citation>**], which often involve a significant number of software artifacts.

(d) Transition towards Open Science

Questions regarding replicability have been previously addressed, for instance, during the RepliCHI series of panels, Special Interest Groups (SIGs), and workshops at CHI conferences from 2012 to 2014[66, 65, 67]. Unfortunately, there appears to have been no further structured discussion on this topic in recent years CHI. Since 2016, the Special Interest Group on Computer-Human Interaction (SIGCHI) has recommended providing supplementary materials for ACM publications [12] to enhance replicability but there are no further discussions available on how those artifacts have been evaluated. Recently, a few universities have begun to reward researchers whose work aligns with standards of open science and transparency, as noted by Schönbrodt and Gollwitzer [55] which is very necessary and well deserved. Over the last two decades, the operational procedures of scholarly social science have been substantially modified to facilitate the goals of open science [39, 40, 23]. Many journals and conferences in diverse domains have started trying to adopt reproducibility standards. However, the transition toward open science is still ongoing with its challenges. Recognizing that open science fundamentally concerns behaviors, various established theories of behavior change, including the Behaviour Change Wheel [29]. Studies have been done to understand how to enhance the adoption of open science practices among researchers [37, 38] and journal editors [33]. Multiple institutional stakeholders—funders, disciplinary associations, data repositories, universities, publishers, preprint servers, and journals—possess the capacity to influence research conduct. However, the transition towards open science remains an ongoing effort and an open-ended question to implement it globally.

3. Methodology

We take an exploratory, survey-based approach for a comparative analysis of researchers' perspectives on reproducibility, replicability, transparency, and open science in India and the USA.

(a) Survey recruitment

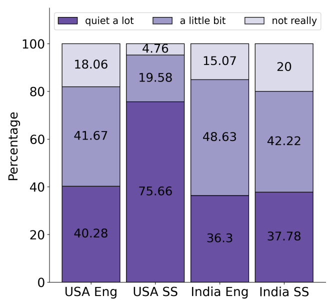
We selected 25 universities randomly from the top 100 universities in India based on the National Institutional Ranking Framework (NIRF) [49]. We have maintained the diversity of the location during the selection of these universities so that the responses should not come from a certain location. Likewise, we selected 25 universities randomly from the top 100 in the USA based on 2023 US News and World Report rankings [35]. *The full list of universities from which participants were recruited is available on the paper's Github repository* (link below).

We directly emailed research faculty listed on departmental web pages using email addresses collected via web scraping of Universities' directories. We targeted the following disciplines in the social sciences: economics, political science, education, psychology, sociology, and marketing. From engineering, we targeted: computer science engineering; electrical engineering; electronics engineering (India); and mechanical engineering. In total, we emailed 4300 faculty members in India (1268 social sciences, 3032 engineering) and 4400 in the USA (2100 social sciences, 2300 engineering). Our email contained a link to the survey, deployed as a Google Form. A one-time follow-up email was sent to all recipients approximately two weeks later. As the summer vacation was there during the survey we got lots of responses where the faculties were not available for a duration. We filter out those emails and send them a third reminder after their vacation time. A pilot version of the survey was created and pretested before deployment. The final survey instrument included a total of 20 questions and 11 questions were closed-ended. Participation was voluntary for this study. A total of 452 respondents completed the survey, 191 from India and 261 from the USA. This represents a 4.44% response rate from India and 5.93% from the USA. Specifically, we have 45 responses from social science researchers in India, 146 from Indian engineering, 190 from social science in the USA, and 72 from USA engineering.

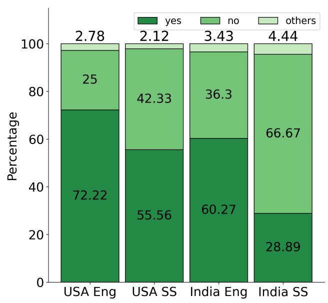
(b) Data collection and analysis

Our survey protocol asked participants to share their perceptions of the state of reproducibility and open science in their respective academic communities and disciplines, factors they believe contribute to the lack of reproducibility and replicability of findings, challenges, and opportunities to promote reproducible research practices. The survey takes approximately 15 minutes in order to maximize full responses. time to complete. The survey was a combination of open-ended and close-ended questions*Our complete survey protocol along with the complete set of anonymized survey responses is available on the paper's Github repository:* `https://github.com/Tatianachakravorti/SurveyData`.

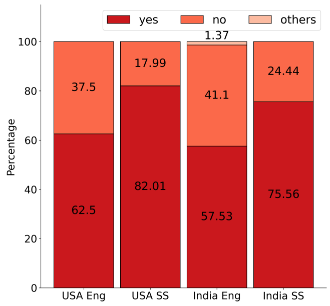
Survey responses were analyzed using descriptive statistics and exploratory data visualizations. Open-ended questions (free text responses) were analyzed using thematic analysis [6, 61]. This qualitative data analysis approach uses a thorough examination of free text responses to uncover patterns and derive themes related to the research questions. Two researchers examined all open-ended responses to identify themes relevant to research questions and establish initial codes. After that, codes were organized into categories based on similarities and relationships. Lastly, we refined these categories, assigned names to each theme, and crafted a



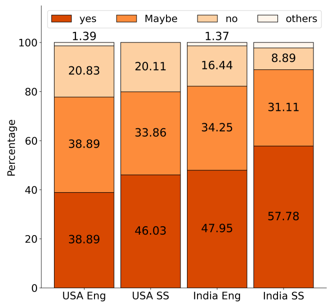
(a) Have you heard much about the "reproducibility crisis" in science?



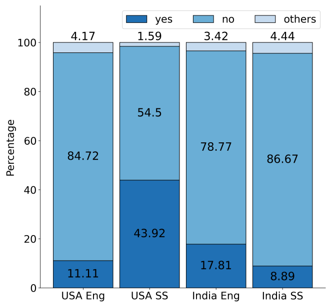
(b) Have you ever tried to repeat a research study someone else published?



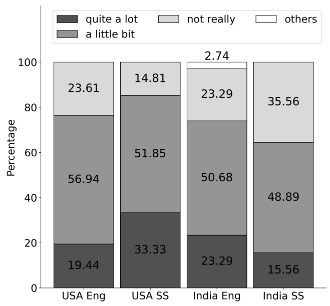
(c) Have you heard much about the "open science" movement?



(d) Should reproducibility and open science be a part of undergraduate curriculum?



(e) Have you ever pre-registered a study?



(f) Have you been asked to share research materials during the review process?

Figure 1: Survey responses by country and domain (Eng=engineering; SS=social science)

conceptual framework to address our research questions with the whole team. The overall study plan was IRB-approved by the university before starting the data collection.

4. Findings

(a) Awareness and concern about reproducibility and replicability

We began by asking respondents have they heard about the reproducibility crisis in science or not. Approximately 83.76% of surveyed researchers in India indicated some level of familiarity with the reproducibility crisis in science. In the USA, awareness reported over 91%. This replication crisis is highly talked about in the USA because 65.5% researchers voted that they have heard about this quite a lot but in India this percentage is 36.64%.

Breaking these totals down further, we observe appreciable differences between disciplines as well. More than 94% of social science researchers in the USA are aware of the reproducibility crisis vs. 81.95% in engineering. While, in India, the awareness of engineering background researchers, with 84.93% and 79.99% in the social sciences endorsing awareness of these concerns (see Figure 1a). Additionally, we explored the respondents' perceptions of their peers' awareness of the crisis. We find that 26.17% of participants from India and 17.62% from the USA believe their peers to be completely *un*aware of the replication crisis. These statistics underscore differences in open discussions about scientific credibility and practice in India and the USA.

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(b) Factors contributing to lack of reproducibility

The researchers were asked about the factors for lack of reproducibility in their fields. The most significant factor is the unavailability of raw data for all the researchers. Specifically, an average of 57.57% of Indian researchers and 58.43% of USA researchers identified the unavailability of raw data as a significant obstacle. The unavailability of code is a more significant crisis for engineering researchers compared to social science because of the type of research, 58.33% from the USA and 53.42% from India mentioned it as an important factor in increasing the reproducibility crisis. Selective reporting was also a concern, with 64.75% of American researchers and 48.24% of Indian researchers recognizing it as a significant issue. Low statistical power was identified as an important concern in social science research. In fact, 42.63% of social science participants from the USA and 22.22% from India identified low statistical power as a contributor to lack of reproducibility. Publication pressure was another important factor, with 57.85% of respondents from the USA and 45.94% from India citing it over the domains. Looking critically, 62.63% social science researchers from USA selected publication pressure as a significant factor for the reproducibility crisis. Insufficient peer review was mentioned by 30.54% of Indian researchers compared to 21.26% from the USA. All the details about the responses by domains have been provided (see Figure 3).

Some other factors also mentioned by the researchers are No incentives, lack of diversity in the sample population, lack of reliable data/sloppy work/fraud, unavailability of valid arguments, declining moral standards, privacy issues, industry boundaries, no funding, less valued, and constant demand for novel research. One of the USA researchers mentioned that the skill of the replicators is also another factor.

> *skill of the replicator: people just don't know what they are doing. So some wet-behind-the-ears graduate student takes it upon themselves to try and replicate something and miss codes the variables. Could open code fix that? Sure, but we're talking about missing value code-level mistakes. People just need to learn how to code.* respondent from USA, sociology

Hardware studies are difficult to reproduce because of the high cost.

> *Intrinsic difficulties in producing the hardware required to perform tests, and the intrinsic high cost of performing human biomechanics research studies. And: who is going to fund this?? Granting agencies rarely fund new work we propose, let alone propose to repeat someone else's iffy work.* respondent from USA, mechanical

Also, it was observed that researchers mentioned qualitative research is hard to reproduce.

> *Qualitative research is hard to "reproduce" given the time constraints associated with its inception. Thus, it seems out of balance to focus on one type of study to "reproduce" ignoring a large type of work. This would seem to further divisions between quant and qual work that the discipline has sought to lessen over the years.* respondent from USA, sociology

(c) Experiences reproducing and replicating others' findings

Reproducing and replicating others' work is fundamental to scientific research. Approaches to do so vary based on the nature of research and norms within disciplines. When asked about their experiences replicating others' work, many researchers indicated that they repeat others' experiments before extending them in their own studies. In India, 52.87% of respondents indicated that they have tried to replicate others' research, compared to 59.77% in the USA. Subsequently, researchers who reported having engaged in replication attempts were asked to share insights about their experiences as an open-ended question. Very few Indian researchers who reported having tried to replicate others' research reported having obtained affirmative results with the remaining majority reporting unsuccessful or only partially successful results.

Looking at disciplinary impacts, we find that 55.25% of social science researchers in the USA have attempted to replicate others' research vs. 28.89% in India which is very low (see Figure 1b.) In engineering disciplines, 72.22% of participants from the USA and 60.27% from India have tried to replicate others' findings.

Open-ended responses indicated that this difference may be attributed to differences in access to resources required for replication, e.g., funding, and computing. In fact, researchers in both countries reported similar challenges for replication attempts. The most frequent among these challenges were resource constraints, specifically, time and money, although this is a significant problem in India compared to the USA. An open-ended question in our survey asked respondents to share their experiences when engaging in reproducing and replicating others' findings. We analyzed these responses using thematic analysis, as described above. Following, we detail extracted themes.

(i) Insufficient detail provided

Respondents who reported that they could only partially replicate existing studies, most mentioned lack of adequate information provided in the paper as the primary reason. Participants emphasized the importance of effective documentation for enabling reproducibility, noting that the specific requirements of this documentation vary by domain. For example, one respondent noted the importance of documenting model hyperparameters.

> *I work in the area of applications of deep learning (DL) to IoT. Most of the times, I have observed that the performance results for the DL models are not really replicable. The reason could be the authors don't share all the hyperparameters for model training. However, even after trying with a range of hyperparameter settings, we couldn't replicate the results. This even happens for the A* conference papers. Hope with your findings and the corresponding publications, the researchers will start thinking about sharing the required information to reproduce the results.* -respondent from India, engineering

In some cases, a successful reproduction or replication was achieved by contacting the study's authors to fill in missing information, highlighting the importance of cooperation and collaboration.

> *It went well, we had to contact the authors to get some details that were not available in the paper, but they were responsive. Our results were affirmative.* -respondent from USA, computer science

However, other respondents reported instances where authors did not respond to their inquiries. **Particularly for researchers in India, contacting a study's original authors and receiving a response appears to be more challenging.** While India is increasingly engaged in international networks, the country still faces barriers in this regard, influenced by geopolitical and economic factors. These barriers may play a role in lack of scientific dialogue.

> *Many times the code and data can be obtained from the researchers. However, sometimes they do not respond and do not make the data/code available either. That is quite frustrating really. However, sometimes the easy way out is just to implement ourselves, compare, and then report in the paper, mentioning the code/ data was unavailable.* -respondent from India, information science

(ii) Success Dependent on Authors' Cooperation

Requests for additional information or data from authors sometimes led to successful reproduction, highlighting the importance of author cooperation and community support.

(iii) Conflicting results

Even when all relevant information and artifacts were available, some researchers found themselves unable to successfully reproduce published findings, often obtaining conflicting results with those reported in this original work. This experience was pervasive among researchers surveyed in both countries.

> *We had enough information to repeat the study, a computer design study which was published at a well-known conference, but we got conflicting results.* -respondent from USA, computer science

> *Tried to simulate based on the details provided by the author in the paper, but failed many times to reproduce the results shown.* -respondent from India, electrical Engineering

(iv) Affirmative results

Optimistically, many of our participants reported successfully reproducing and replicating findings in the literature, and many of them went on to extend those findings in their own studies. This was particularly the case for our respondents from the USA; who reported having affirmative results when they replicated others' work which is much higher compared the India. Very few researchers mentioned about the affirmative results from India. But overall the statistics highlight that it was not very easy for the Indian researchers. All these percentages are from the group that tried to replicate others' work.

> *Successful. The reproduction was affirmative. I have also had others repeat studies my group has conducted.* -respondent from USA, computer science

(v) Ethical Concerns

Concerns about the authenticity of the data and the validity of results were raised, with some participants encountering fake data or unclear methodologies that hinder reproducibility.

> *Not sufficient information was available. Requested to provide raw data. But analyzing the data revealed that it is fake. And it was of no use. But the article was published in a good journal.* -Indian Respondent

(vi) Hopeful progress

Better community practices such as sharing codes and detailed project pages (e.g., on platforms like GitHub or PapersWithCode) have made reproducibility easier over time. Proper documentation and accessible data and code are key to successful reproduction. Respondents indicated that in the past, reproducing others' work was significantly more challenging due to inadequate documentation and the absence of code and data sharing. However, the situation has considerably improved in step with the open science movement.

> *Earlier years it was tough. Many times code was not public and contacting the authors was fruitless. Also, the project pages were not well documented. So things were tough that time. Now the environment has changed. As others in the community make code public and make dedicated project pages, it is easier to reproduce them.* -Indian Respondent Computer Science

> *In three tries the answers vary. Case1 (in 1986) was a very difficult and time-consuming process that reflected the low standards of research process control at the time. Case2 (in 2006) went much better and the outcome was much closer correspondence between the published results and my student's replication of them. Case3 (in 2019) was an exact replication using the code the authors had posted on OSF.* -respondent from USA, sociology

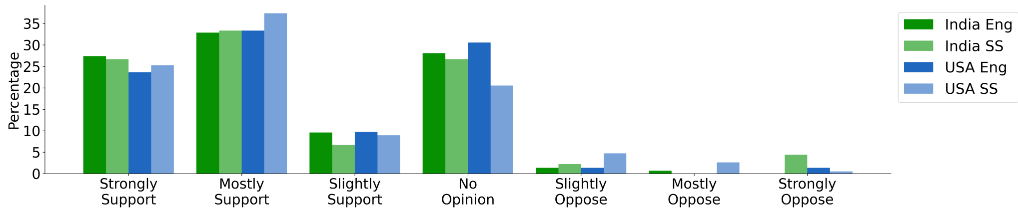

Figure 2: Opinions about the open science movement

Experiences with reproducibility are varied; while some have never attempted it, others have had different levels of success. There are reports of both complete failures and successes in reproducing results, reflecting a broad spectrum of challenges and outcomes in the field.

(d) Attitudes towards open science

More than half of respondents in both countries reported some awareness of the open science movement and its aims. Specifically, in the USA, 76.25% of respondents indicated awareness vs. 61.78% in India which is a good sign. In both countries, social science researchers were more familiar with the open science discourse than engineers (see Figure 1c). In India, 75.55% of respondents from social science mentioned they have heard about the open science movement but the awareness for the Engineering domain is 57.53%. Overall support for open science principles was assessed on a 7-point Likert scale, ranging from *no support* to *strong support* (see Figure 2). We observe most of the respondents support open science practices, and the percentage for strong support is nearly the same for both countries.

(i) **Reasons not to Support Open Science**

Respondents who indicated no support or slight support for the open science movement mentioned their concerns. After analyzing the responses from the Indian research we observe that Open Access fee is a major barrier for them. The open access fee is too high for them and they can not afford it. Also, some of them think if it is a paid journal then the quality of the paper degrades and the journals can be irresponsible. Also, it was observed that the role of open science is not clear to many.

> *Unless I know what it really is, guessing an answer here would be unrealistic. Is this the same as "Open Access"? If yes, I oppose it. This 'paid stuff' has diluted science alike.* –respondent from India, Electrical

Another reason to not support open science is because it has less diversity and is more restricted to the elite institutions which can increase the inequity.

> *If I were to not wholeheartedly support it, it might be because open science movement is restricted to elite institutions, led by researchers from developed countries where the resources available and the challenges faced by the researchers are very different from the ones faced by researchers from the developing countries (participant unavailability, low incentives for participation in research, power failures, lack of lab space, non compliance of participants to protocol despite consent unique to developing countries, some institutes do not have ethics board to approve a study etc).* -respondent from India, psychology

Like Indian researchers, we observed some of the researchers from the USA think that the open access fee for publication can increase inequality as many universities don't have sufficient funding.

It shifts costs from wealthy publishers to scholars who can't afford it and disproportionately harms junior scholars and those from poorer institutions so it exacerbates inequality across the board. – respondents from USA, Political science

Respondents cited concerns about the time and cost associated with sharing data and code. Several respondents compared the sharing of resources to revealing proprietary work before completing a long-term project which can increase their competition. They shared they could write multiple papers based on a single dataset or piece of code, and that they were reluctant to share with others to avoid heightened competition.

Some code takes years to produce and researchers are still publishing papers from it after one paper is published. Sharing it means that you are essentially giving away your proprietary work before a long-term project is complete. -respondent from USA, sociology

if we open everything then we take the risk to have more competition. That's good to open but after a few years so that we can still publish our ideas before all the other people use our published work. If a lot of people have access to our last results and can replicate them, then they can easily work on the same topics (assuming they have more students in their labs) –respondents from USA, engineering

Additional factors contributing to the lack of support for open science include the belief expressed by some researchers that the open access movement lacks inclusiveness and disadvantages less-resourced individuals. Participants expressed concerns related to the low quality of peer reviews in many open-access journals. In addition, researchers engaged in human subjects and qualitative research expressed difficulty in making all aspects of their work openly accessible due to privacy concerns.

Human subjects research requires sensitivity for confidentiality and privacy. In public health research there can be powerful opponents who may use data inappropriately. People untrained in statistics and epi could obfuscate important health issues - erodes respect for experts. -respondent from USA, social science

One researcher from the USA specifically mentioned that the federal government should take the necessary steps for proper open science practices. The current movement is not very clear and has lots of flaws.

The current funding model makes it completely impractical. I'd like there to be more open science, but federal grants are not willing to pay for it in any meaningful way. For example, the new OSTP memo on open access publishing and data was put out a year ago, no follow-up from OSTP, and now each federal agency is coming up with their own set of requirements based on their interpretation of the memo. It's going to be chaos for folks who have funding from multiple agencies because now they're all going to have different requirements AND none of them are going to pay for the time and effort required to comply with everything. I went to NASA's webinar on their new policy and they had very vague answers to some pretty basic questions from faculty and scientists about their new policies - it was a mess. Either the federal government gets serious about open science or it doesn't happen. -respondent from USA, mechanical

(ii) Attitudes towards Preregistration

We explored participants' perspectives on a core open science practice, namely, preregistration. Experience with preregistration varies between India and the USA, with only 15.71% of researchers in India reporting preregistration compared to 34.86% in the USA. Notably, in India, only 8.88% of social science researchers reported having ever preregistered a study, as opposed to 43.91% in the USA. Notably, however, the percentage of engineering researchers in the USA who have preregistered work was lower at 11.11% than in India at 17.81% (see figure 1e). The

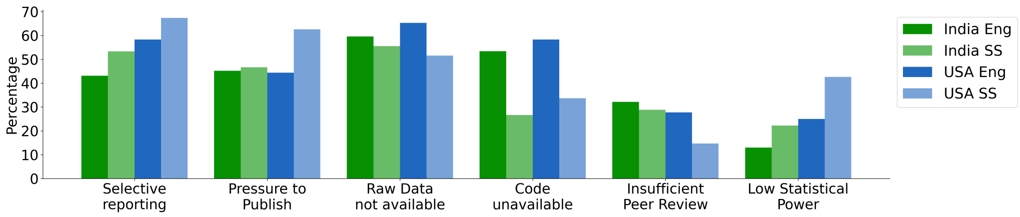

Figure 3: Factors contributing to lack of reproducibility

results underscore how disciplinary culture can be as meaningful, if not more so, than country-specific norms. The perceived necessity for preregistration is not consistent across all departments and is highly research-dependent according to the researchers. The major observation regarding pre-registration is that the whole process is not very clear to the researchers.

> *I think so? I've filled out an IRB for a human subjects study - does that count?* –respondent from USA, Mechanical engineering

It is noteworthy that while pre-registration is less common in engineering, the field still upholds rigorous scientific methods and practices.

> *My work does not involve statistical work of the kind implied in this question. We are physical scientists so we don't need pre-registration.* -respondent from India, mechanical engineering

A respondent pointed out that preregistration may not be relevant for most studies, further emphasizing varied perceptions among researchers about the utility of preregistration.

> *Preregistration is stupid for the vast majority of studies. If you are doing a high-risk/cost intervention hypothesis test, fine. But very few people are doing that.* -respondent from USA, sociology

(e) Peer Review to ensure reproducibility

We asked our participants whether they had ever been asked to share data files, code, or other materials during peer review of their own work. This question was open-ended and we used thematic analysis to analyze their responses. To explore the role of peer review in promoting reproducibility and replication, researchers were surveyed about their experiences with the peer review process. Specifically, they were asked if they had been requested to share data files, analytic code, or other research-related materials during the review. This inquiry was posed as an open-ended question, allowing participants to freely share their thoughts and experiences. Through thematic analysis of their responses, we identified six major themes: Never, Rarely, Yes, provided always, and if accepted (see 1f).

> *Many top computer vision or machine learning conferences now encourage code submission during paper submission. However, as a reviewer (due to time pressure) I am not willing to check the code by running it. So, I think, ultimately it comes down to reducing the load on the reviewers which, in turn, means training more reviewers to do the job right.* -respondent from India, engineering

(f) Institutional challenges and opportunities

As noted, our survey explored obstacles to successful reproduction and replication. These include the unavailability of code or data, unclear explanations of experimental settings, and lack of detailed methodological descriptions. Our survey protocol also allowed respondents to enter

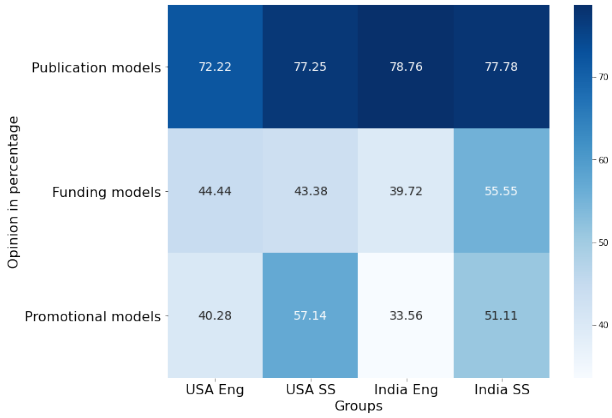

Figure 4: Changes to Models

"other" factors they perceived to contribute to lack of reproducibility in their field. The majority of these "other" issues were institutional or systemic, related to research culture, norms, incentives, peer review processes, and training.

(i) Misaligned incentives

The most commonly noted of these factors across both countries and both fields was **lack of incentives** for reproducing or replicating others work. Few journals regularly publish reproduction, but rather highlight novelty. This has substantial impact given respondents reporting feeling significant pressure to publish. In fact, participants were asked to choose from a range of institutional changes that could help to support reproducible research practices, with the option to select multiple choices. Across both countries, the most commonly selected response was "changes to publication models" (78.53% of researchers from India and 75.48% from the USA).Additionally, 57.14% social scientists from the USA suggested "changes to promotional models" are required to incentivize best practices. In both countries, engineering researchers reported changes to funding models to be equally or more important than changes to promotional models (see figure 4).

In this section, we provided the "other" option to make it more flexible and open to the respondents and many of them responded using this option which contributes to one major incentive would be the rigorous peer review process. According to many the peer review is not sufficient to understand replicability and data sharing. Journals and conferences should not accept papers if the code and data are not provided by the authors.

> *Not pushing the idea that all novel work must be surprising or disconfirming previous folk understanding of an issue.* -respondent from USA, Psychology

> *Review and publication process should really be focusing on the rigor of the methods, not the significance of the results; with valid and generalizable methods, insignificant/unexpected results are still important, which means we thought it wrong.* -respondent from USA, psychology

Changes to the publication models refer to more rigorous peer review, pre-publication code, materials, and data review is required. Some other factors have been mentioned by the researchers as well, measures such as the "Transparency and Openness" standards of APA are starting to help. It's truly a matter of integrity; guidelines can help, and integrity training can help more mentioned by one of the researchers. More emphasis on qualitative research and making theoretically

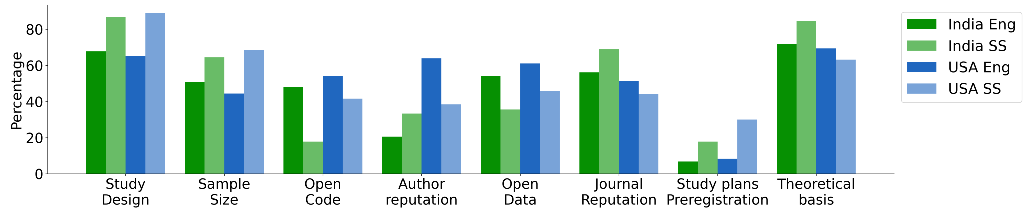

Figure 5: Signals of credibility

informed, convincing causal arguments are necessary too. Less inclination to believe studies just because they use advanced statistical techniques.

(ii) Coursework

A hope of the open science movement is that a global shift toward more rigorous research practices can be achieved through educational efforts targeting the next generation of researchers. We asked participants about their willingness to incorporate reproducibility and open science topics into their coursework. In India, 57.77% of social science researchers and 47.94% from engineering believed it is necessary to add open science and replication topics to current course work. In the USA, these numbers were slightly lower; 46.03% of respondents from social science and 38.89% from engineering believed this is needed (see figure 1d). One of the researchers mentioned his concern to fit this with the curriculum.

> *Yes, it would be great. But I'm not sure how we could fit it into the curriculum.* USA Respondent, Materials Science

(g) Signals of credibility of published findings

We sought to understand how our participants evaluate the credibility of published findings when they see them in the literature, e.g., based on journal reputation, whether authors have shared materials, robustness of study design, and similar. We offered a lengthy list of potential signals and also left space for respondents to include their own, understanding that important signals likely vary across domains. incorporated features from previous surveys into our survey questions, including open data, open code, study design, theoretical basis, sample size, author reputation, and journal reputation. Participants were allowed to select as many features as they deemed important. The survey also sought to identify what researchers consider credible signals/features when evaluating research articles, with participants free to choose multiple factors. Factors of credibility are also very much dependent on the research domains. Every research domain doesn't have the same signals of credibility. Study design and theoretical basis were revealed to be the most frequently identified across both countries as signals of credibility of published findings. Engineering researchers tend to look for open sharing of data and code, whereas social science researchers evaluate the sample size of the study population. Author reputation and journal reputation were also identified as significant factors, particularly identified as such by respondents from the USA (see figure 5).

> *I typically pay extremely close attention to the detail with which the data and analysis are described. When authors are not careful in how they describe what they did, this is a major red flag. Obviously, careful description can mask uncareful data collection, design, and analysis, but it is still a signal of credibility that I look to.* -respondent from USA, political science

Some of the other features mentioned by the respondents are knowledge of the literature, correspondence between theory and evidence, sensitivity checks, ideological biases, and plausibility of conclusions they see during the credibility check for the existing papers.

5. Limitations

Our study conducts a comparative analysis of research cultures in India and the USA, highlighting both opportunities and challenges for enhancing scientific practice. However, it's important to note that the insights and conclusions drawn are specific to these two countries and may not be applicable elsewhere. Therefore, any conclusions derived from our findings should be considered context-specific and have limited applicability beyond the contexts of India and the USA.

6. Discussion and Recommendations

Our study offers an in-depth analysis of researchers' views on reproducibility, replicability, and open science practices in the USA and India, casting light on both commonalities and disparities. While Western nations have more proactively tackled the replication crisis, Indian researchers are becoming more conscious of these issues and are making strides toward embracing open science. Yet, our findings indicate that its adoption faces hurdles in both countries and across fields, although these hurdles are much bigger in India.

Required Incentives: Respondents across contexts highlight the misalignment of prevailing academic incentives, centered around publications, promotions, and funding, as detrimental to engagement with open science practices. They note a lack of appreciation for replication studies in favor of novelty[**kohler2021play**, **key2016we**]. Most of the journals and conferences ask for novel research therefore there are very few available opportunities to publish replication studies. Although some of the conferences like ACM REP started taking submissions for replication studies, however, they are very less and diversified. The most significant incentive needed is publication opportunities, Journals and conferences might consider dedicated opportunities to publish replication studies. The second two important incentives are funding and promotion.

Institutional Support Our findings also suggest the potential value of standing up educational and public-facing initiatives in India, e.g., workshops, consortia, and centers, where questions about reproducibility and replication have simply received less attention. Yet, our findings also suggest that the mere existence of institutions aiming to improve research practices in India can not be successful without effective execution at the grassroots level. A comprehensive integration of resources, including training and access to necessary resources, is needed to facilitate the widespread sharing of research artifacts and open science practices. These resources include but are not limited to time; computing resources; support for data storage and management; and funding for open-access publication fees. Our study suggests universities in both countries should have undergraduate and graduate courses focused on best practices and highlighting existing challenges.

Importance of Badges: We note that new incentives have emerged and should be used as stepping stones for substantial extensions. A notable example is the impact of badges. These simple rewards have a real, measurable impact on engagement with open science practices [52, 53]. The next steps might include the inclusion of badges into reputational metrics and promotional practices. Although most of the conferences and journals still have not adopted this. This can increase the load on reviewers which increases the challenges to implement.

Metric to measure open science: Globally, establishing metrics to measure engagement with open science and replication efforts could help realign academic incentives. The academic institutions should value the researchers whose research is more transparent and open.

Community Bias: Discussions of reproducibility and open science centered in the West have not fully appreciated the challenges faced by researchers working at institutions with fewer resources and less social capital. For example, when attempting to reproduce or replicate a published finding, respondents in Indian research did not get responses from the paper's authors compared to Western countries like the USA is more challenging for them. While it is generally acknowledged that reproduction and replication should ideally be possible without consultation with authors, consultation is still standard practice and ultimately it is a biased practice that favors well-established community members.

Compound Inequities: Some open questions have been raised for further discussion. To have more diversity and equity the open science community should think about the backgrounds of these researchers because many other country researchers like the Indian researchers may not be able to pay the open access fee for the publications. Wealthy institutions and regions can afford open access compared to the poorer ones[50]. This can also increase difficulties for the early career researchers who are less compared to the established ones. Researchers have already observed that the geographic diversity of authors was much greater for non-open access articles than for open access articles[60]. This can increase inequity and open science community should take proper action to control this diversity problem. Therefore, the challenge of affordability of open science publication fees for Indian researchers raises questions about the global implementation of open science.

Bias towards Author Reputation: Our work confirms shortcomings in researchers' approaches to the assessment of confidence in published work. The author's reputation was noted as a meaningful signal of credibility in both countries and across domains. Current ways for researchers to accumulate good or bad reputations, though, are driven by available existing metrics. The ways in which biases with respect to author reputation may be worsened or mitigated by open science practices, e.g., open peer review, is unclear.

Clarify the Purpose and Benefits of Pre-registration: It was very clear from the responses that only social science researchers in the USA are into pre-registration. Most of the researchers are not familiar with pre-registration and some of them have a misunderstanding with the concept. Increase awareness and understanding of what preregistration entails through workshops, seminars, and training sessions. Provide clear, step-by-step guidance and examples of well-executed preregistrations which could include standard templates or checklists that align with various types of studies.

Develop Specialized Modules: There is a huge need flagged by researchers from both countries to have a course for open science and reproducibility. Specific modules or courses are required to be created that focus on open science practices and reproducibility. These modules can be designed as part of the existing curriculum or as optional courses that complement the main coursework.

Rigorous Peer Review: Our work highlights the urgency of reevaluating existing peer review processes. Ideally, the strongest signal of credibility for a published finding should be the fact that it was peer-reviewed and ultimately published. A majority of our respondents expressed dissatisfaction with current peer review processes and suggested that more rigorous mechanisms of research assessment are needed. Researchers expected to publish rigorous, reproducible, replicable work, adhering to best practices of open science are embedded within social, cultural, and economic contexts. Our work makes clear that this context is not uniform and that solutions that do not consider this will inevitably fall short.

7. Conclusion

This study offers valuable insights and recommendations that can significantly benefit the research community by guiding improvements in research practices and policies related to reproducibility, replicability, and open science. The findings can influence policymakers and funding bodies to reconsider how research is evaluated and funded. Encouraging policies that value transparency and replicability can reshape research ecosystems to foster more reliable and impactful scientific outcomes. It represents where India stands in open science practices and what barriers still the Indian researchers are encountering on a day-to-day basis. The necessity for a global reassessment of the economic and reputational biases that currently influence the accessibility and implementation of open science is clear. These biases exacerbate inequities, particularly affecting researchers from resource-limited settings and those early in their careers. Addressing these challenges requires a clear understanding of the diverse contexts in which researchers operate, ensuring that the move towards open science is inclusive and equitable.

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