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Research Reproducibility Ethics of Scientific Research in Higher Education

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Abstract

Research reproducibility is a critical aspect of scientific research that has been gaining increasing attention in recent years. In higher education, it is considered a crucial issue that requires attention due to the significant implications for public health and safety. Despite the growing awareness of the need for greater transparency, rigor, and ethical principles in scientific research, there are still many challenges that need to be addressed. This research article aims to explore the ethical considerations related to research reproducibility in higher education. Specifically, we examine the current state of research reproducibility in higher education, the challenges and opportunities for improving research reproducibility, and the implications for ethical principles in scientific research. To address these challenges, we propose adopting open science practices, sharing data and code, and promoting greater collaboration and openness in research practices. By doing so, we hope to contribute to the ongoing discussions around research reproducibility and promote greater transparency, rigor, and ethical principles in scientific research.

Keywords: Reproducibility, Challenges, Research Ethics, Computational Biology, Higher Education

Historical Background

The quality of science lies in its ability to prove its hypotheses through accurate scientific claims and draw conclusions based on evidence and systematic observations performed by scientists. To prove scientific descriptions, experimental techniques need to be used. Although it requires careful attention to minimize the risk of errors during research, both wet and dry lab work are essential. Ideally, experimental research should describe the steps in their published work in detail so that other scientists can easily replicate them. "Getting the same results and minimizing experimental errors in research is important to achieve fundamental visions in nature, such as the measurement of the speed of light, regardless of the experimental methods used. However, sometimes uncertainties in results are interpreted differently in new branches of science. For example, Schrodinger's development of the theory of the first passage of times reported opposing experimental data about the existence of fractional elementary charge (Schrödinger, 1915).

Introduction

Research reproducibility is a crucial aspect of scientific research that has been gaining increasing attention in recent years (Baer & Gilmore, 2018). It refers to the ability to obtain consistent and reliable results when repeating a scientific study using the same data, methods, and analysis. However, there have been growing concerns about the reproducibility of research findings across various fields, including biomedical and computational research (Ioannidis, 2005).

In higher education, research reproducibility is considered a critical issue that requires attention (National Academy of Sciences, 2016). This is because scientific research forms the basis for many policy decisions and has significant implications for public health and safety. In recent years, there has been a growing awareness of the need for greater transparency, rigor, and ethical principles in scientific research to ensure that research findings are reliable, valid, and impactful (Nosek et al., 2018).

Many factors can contribute to challenges in research reproducibility, including selective reporting of results, publication bias, and inadequate descriptions of methods and data (Open Science

Collaboration, 2015). To address these challenges, researchers, journals, and institutions are adopting open science practices, sharing data and code, and promoting greater collaboration and openness in research practices (Stodden, Seiler, & Ma, 2018).

In this research article, we aim to explore the ethical considerations related to research reproducibility in higher education. Specifically, we will examine the current state of research reproducibility in higher education, the challenges and opportunities for improving research reproducibility, and the implications for ethical principles in scientific research. By doing so, we hope to contribute to the ongoing discussions around research reproducibility and promote greater transparency, rigor, and ethical principles in scientific research (Diaba-Nuhoho, & Amponsah-Offeh, 2021).

Research reproducibility refers to the ability to obtain consistent and reliable results when repeating a scientific study using the same data, methods, and analysis. In recent years, there has been growing concern about the reproducibility of research findings across various fields, including biomedical and computational research. The replication crisis has highlighted the need for greater transparency, rigor, and ethical principles in scientific research to ensure that research findings are reliable, valid, and impactful for the betterment of society (Munafò et al., 2017).

Many factors can contribute to challenges in research reproducibility, including selective reporting of results, publication bias, and inadequate descriptions of methods and data. These challenges can lead to errors and inconsistencies in research findings, which can have significant consequences for public health and policy decisions (National Academies of Sciences, Engineering, & Medicine, 2019).

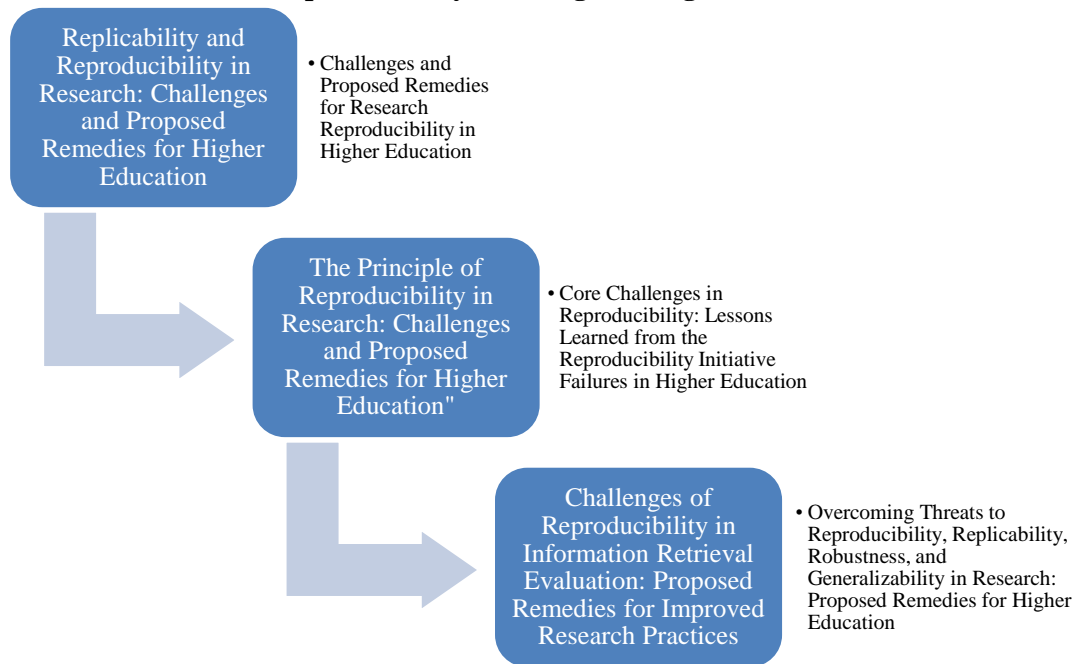
To address these challenges, researchers, journals, and institutions are adopting open science practices, sharing data and code, and promoting greater collaboration and openness in research practices. Additionally, the use of modern technology and databases can help to promote research reproducibility and reduce errors and inconsistencies in research findings (Chakravorty et al., 2022).

Overall, promoting research reproducibility requires a concerted effort from all stakeholders in scientific research to prioritize transparency, rigor, and ethical principles. By working together and adopting open science practices, we can advance knowledge and promote scientific integrity for the benefit of all individuals and society (Hollmanna et al., 2022).

Review of the Literature

According to the literature, scientists have been aware of this experimental issue for years and have been trying to overcome it. Globally, the use of computers in the research field to analyze research data helps to minimize experimental errors. However, the use of digital computers in the research field is thought to be an exact machine, and results can be reliable if suitable methodologies and experimental principles are used." "Very little attention is paid to the accuracy of potential implementation for errors, as well as the differentiation found in hardware and software versions. It is also difficult to redesign these systems after just a few years or months. Furthermore, we often do not have any idea how accurately someone analyzes computational experimental data. According to a study, geophysicist Stanford Jon Claerbout was the first computational scientist to report this issue (Claerbout & Karrenbach, 1992)." "Donoho and Victoria reviewed Claerbout's work and presented it to a large-scale audience through Peng in 2011 (Donoho et al., 2009). According to Claerbout's definition, "reproducing" means running the same software with the same input and obtaining the same results (Rougier et al., 2017). He also concluded that reproducibility of computational-oriented research no longer requires a skilled person and can be done by a common individual (Claerbout & Karrenbach, 1992). Furthermore, the replication of published research work is defined as writing the work again and running the data in new software based on computational research work presented in the original published research work and obtaining similar results (Rougier et al., 2017). These definitions of "replicability" and "reproducibility," according to Claerbout's terminology, are also mentioned in behavioral, economic, and social sciences (Bollen et al., 2015)." "On the other hand, a standard textbook of analytical chemistry states that the use of "replicating" and "reproducibility" is at odds with the terminology in experimental sciences (Miller & Miller, 2000, p.6).

Framework for Research Reproducibility Challenges in Higher Education



Enhancing Replicability and Reproducibility in Research: Challenges and Proposed Remedies for Higher Education"

In recent years, the scientific community has placed increasing emphasis on replicability and reproducibility as fundamental principles of the research method. According to Claerbout's definition, 'reproducing' research involves executing the same software with the same input and obtaining the same results (Rougier et al., 2017). This has led to the understanding that reproducibility in computational-oriented research is no longer restricted to skilled individuals but can be achieved by anyone (Claerbout & Karrenbach, 1992). Scientists across disciplines have made efforts to improve the reproducibility and replicability of research to facilitate discoveries and inventions. This review aims to discuss the different implementations established in various fields to enhance the reproducibility of research in higher education. Additionally, we explore the different aspects of replicability and reproducibility problems in research methodology that have been reported in the literature.

Although the principles of reproducibility and replication are often thought of as common sense, their theoretical underpinnings and practical implications are more complex than they may initially appear. While reproducibility issues are commonly associated with scientific metrics research, which relies heavily on measuring and analyzing scholarly literature, they can also arise in other research fields due to minor changes in methodological practices. However, for this discussion, a deeper exploration of research motivation is not necessary. Instead, we will focus on the importance of providing a thorough research description, including methodology and choices made in the research process (National Academies of Sciences, Engineering, & Medicine, 2020).

Reproducibility in Information Retrieval Evaluation presents a unique set of challenges. Information Retrieval (IR) involves classifying information resources based on user needs and providing a wide range of information to society and industry applications, such as Web search engines (Croft et al., 2009), academic property and patent search seminars, and various others (Lupu & Hanbury, 2013). The performance of an Information Retrieval system is determined by its efficiency and effectiveness in retrieving and ranking informational resources based on their relevance to the user's needs. However, it is also important to consider whether the system is suppressing relevant information or not ranking it highly enough. The goal of using IR in reproducibility is to reduce the information overload by providing efficient and effective access to relevant information." "However, there are several sources of uncertainty in Information Retrieval, including unclear user information desires, unstructured information sources, and subjective notions of relevance. Experimental evaluation is one of the few means of testing the performance of an information retrieval system. The standard for experimental evaluation is the Cranfield paradigm, which involves a series of experimental studies using samples collected from a real domain of interest. However, to

apply the Cranfield paradigm, it is necessary to have real user information and relevance judgments to determine which topics are relevant to which related documents (Harman, 2011). This process involves human judgment and is therefore subject to potential biases and errors." Experimental evaluation at an international level typically involves large-scale evaluation promotions that are publicly open to participants. Examples include the Text Retrieval Conference (TREC) in the United States of America (Harman and Voorhees, 2005), the Conference and Labs of the Evaluation Forum (CLEF) in Europe (Ferro, 2014), the NII Testbeds and Community for Information access. Research (NTCIR) in Asia and Japan, and the Forum for Information Retrieval Evaluation (FIRE) in India (Ferro, 2014). "Studies have shown that every year, a large amount of valuable scientific data is produced through various research activities, which forms the basis for further scientific advancements and technological innovations (Ferro et al., 2011). In many scientific disciplines, including computer science, reproducibility has become a major concern (Freire et al., 2016). This is especially true in the field of Information Retrieval, where artificial review and results have become increasingly prevalent. As a result, the Association for Computing Machinery (ACM) has recently increased its attention to reproducibility in IR (Ferro et al.2011)." To address the issue of reproducibility in Information Retrieval, various infrastructure and initiatives have been developed. These include infrastructure to manage experimental data (Agosti et al., 2012a, 2012b), the usage of private data in evaluation (Callan & Moffat, 2012), reproducibility baselines (Arguello et al., 2015; Di Buccio et al., 2015), and the introduction of evaluation as a service (Hanbury et al., 2015). Furthermore, reproducibility has become a major part of the review process during conferences and in dedicated tracks, such as the new ECIR reproducibility track (Fuhr et al., 2015; Ferro et al., 2016a).

The concept of reproducibility has been a fundamental tool of science since the establishment of the Royal Society's philosophical dealings in 1665. It has been used by scientists to establish the significance of their research and validate their scientific discoveries. However, as the process of scientific discovery has evolved, new methods and technologies have been introduced in a changing regulatory and social environment, leading to various challenges of reproducibility and proposed remedies. The Sackler Calculum on 'Research Reproductive Capacity: Problems and Proposed Treatments', held from March 1-10, 2017, brought together a wide range of stakeholders from the research community to discuss issues of transparency and reproducibility in modern research contexts. The discussions highlighted the need to address two related questions: first, what does reproducibility mean in different research contexts; and second, what treatments can increase transparency and reproducibility in research practices?

The challenges of achieving reproducibility in scientific research have become increasingly evident in recent years, as various reproducibility initiatives have faced difficulties and highlighted core challenges.

Determining how to report and address reproducibility concerns in the biomedical research field is crucial for improving the quality of peer-reviewed publications and research work standards. To achieve this, guidelines are needed on study design, analysis methodology, implementation standards, and meta-analysis of several studies related to the field to produce shared results. Additionally, forming a consortium to implement standardized procedures and reproduce data could help address reproducibility concerns in the field.

Reproducibility initiatives (RIs) are another method of addressing reproducibility concerns. RIs are well-intentioned, high-profile, systematic harmonization measures that seek to change the outdated procedure of scientific self-improvement. However, the effectiveness of this methodology has been called into question, as the results of RIs to date have been different from additional independent self-correction studies that have reproduced the innovative search.

Since RIs have been shown to produce different results from the actual study, they cannot provide conclusive evidence about the need for additional studies. Moreover, the RI approach does not provide a viable alternative to scientific self-improvement, nor is this its intention. A failed attempt by an RI is also likely to damage the credibility of the author of the original discovery. Reproducibility is often confused with duplication, which refers to an exact duplicate of an innovative and well-known or unknown technique, while reproducibility refers to the ability to obtain similar results in a different environment or with different motivations. In reproducibility studies, different research results may occur due to environmental and motivational differences. However, the RI

agenda has had negative results in its efforts to increase reproducibility and has produced tangled efforts to determine whether research is realistic or not.

Overcoming threats to reproducibility, replicability, robustness, and generalizability is crucial for improving the quality and credibility of scientific research. Efforts to address these threats may include improving the transparency of research methodologies and data sharing, increasing interdisciplinary collaborations, conducting replication studies, and using more robust statistical methods. Additionally, promoting open science practices, such as pre-registration of study protocols and sharing raw data and materials, may also help improve reproducibility and scientific rigor.

The crisis of reproducibility also affects the microbiological sciences and has implications for related research fields. Microbiologists have struggled to overcome reproducibility issues and make their research more valuable. It is challenging to ensure that research methods and results are clear, and this problem is exacerbated in interdisciplinary fields, such as microbiome research. Nevertheless, efforts to address reproducibility challenges in microbiology may include developing standardized protocols, increasing transparency in experimental procedures, and sharing raw data. Additionally, promoting collaboration and interdisciplinary approaches may aid in improving reproducibility and scientific rigor. There are several reasons why a scientific researcher may not be able to reproduce their research results, including issues with experimental design, equipment calibration, sample preparation, or data analysis. Even when researchers can reproduce their results, they may not be 100% accurate due to small variations that are inherent in scientific experiments. However, when researchers fail to reproduce earlier results, it can provide valuable insights into microbial life and scientific protocols. Such failures can prompt researchers to question assumptions, refine experimental methods, and increase transparency and rigor in the scientific process. This viewpoint outlines a framework for identifying and addressing factors that can compromise the robustness, reproducibility, replication, and overall quality of microbiome-related research. Rather than simply recognizing signs of crisis in the work of others, we need to appreciate the social and technical challenges that can hinder reproducibility in our research and related fields. Such challenges may include issues with data management and sharing, experimental design, statistical analysis, and communication barriers between interdisciplinary teams. By addressing these challenges, we can work to enhance the reproducibility and reliability of scientific research in the field of microbiome research and beyond.

Enhancing rigor and reproducibility is a key objective for scientific research in all fields, including microbiome research. There are several strategies that researchers can employ to enhance rigor and reproducibility, such as promoting transparency and open science practices, using robust statistical methods, and conducting replication studies. Additionally, developing standardized protocols and operating procedures, implementing quality control measures, and ensuring the accuracy and completeness of data management and sharing are important steps to enhance scientific rigor and reproducibility. By implementing these strategies and fostering a culture of open communication and collaboration, researchers can work together to improve scientific research practices and promote the advancement of knowledge in the field of microbiome research and beyond.

Biomedical research is increasingly reliant on computational tools, but ensuring the reproducibility and transparency of research conducted using these tools is a complex issue. Different academic institutions, publishers, and funders have varying approaches to promoting open software, open data, and reproducibility in computational research. While some publications may provide software with documentation and source code that is available and transparent, this is not always the case. To address this issue, scientists and publishers can work together to establish clear standards and guidelines for promoting reproducibility and openness in computational research, such as requiring the publication of source code and data, ensuring proper documentation and version control, and implementing quality control measures. By increasing transparency and reproducibility in computational research, we can enhance the quality and reliability of biomedical research and ensure that computational tools are used effectively to advance scientific knowledge (National Academies of Sciences, Engineering, & Medicine, 2019).

This perspective challenges the central role of peer review in assessing technical accuracy and scientific merit, particularly in the context of incomplete or insufficient sub-information for educational software platforms. Limitations and biases can arise from such incomplete information, thereby compromising the validity and reproducibility of research findings. In response, we propose

several recommendations to improve transparency, reproducibility, and consistency in computational biology, especially as they relate to standards in the life sciences curriculum. Such recommendations may include developing standardized protocols for data management, promoting open science practices, and increasing transparency in experimental procedures. Additionally, implementing quality control measures, refining statistical methods, and fostering collaboration and interdisciplinary approaches may help to ensure the reliability and reproducibility of research findings in computational biology and related fields (National Academies of Sciences, Engineering, & Medicine, 2019).

Challenges for research reproducibility:

Gene editing technologies have revolutionized biomedical research and are expected to play a significant role in clinical sciences. However, as their use becomes more widespread, unexpected challenges have emerged in both research and clinical settings. The literature discusses these challenges, which include the need for thorough model validation in research contexts. This is necessary to ensure the accuracy and reliability of findings, particularly when using gene editing technologies. Furthermore, it is important to consider the potential unintended consequences of gene editing in both research and clinical applications. Ethical considerations must also be considered when using these technologies on human subjects, given the potential for long-term health impacts and other uncertainties. Overall, it is essential to approach gene editing technologies with careful consideration and to prioritize rigorous research methods and ethical practices to ensure their safe and effective use in advancing biomedical knowledge and clinical care (Zhou et al., 2022).

Discovering empirically based best practices in computing education is crucial for ensuring the effectiveness of computer science programs. These best practices can help educators improve student learning outcomes, increase engagement, and promote diversity and equity in the field. To identify best practices, researchers may use a variety of methods, such as conducting experimental studies, analyzing data from educational programs, and synthesizing findings from existing literature. Additionally, collaborations between researchers and educators can help to identify and implement effective teaching techniques and approaches. Overall, discovering empirically based best practices in computing education requires a commitment to rigorous research and a willingness to experiment with new teaching strategies and methods (Thomas, 2016).

Despite the existence of some experimental leading practices in computational education, there are legitimate concerns about the lack of knowledge replication and reproducibility in the field of science, including educational and computational education systems. Without further experimental evidence from reproducibility in research, replication of results, and meta-analytical research studies, it is difficult to confirm the authenticity of best practices. Educators and researchers must work together to prioritize research that identifies and validates effective teaching techniques in computing education. This can be accomplished through rigorous research methods, such as randomized controlled trials, replication studies, and meta-analyses. Additionally, increasing transparency and openness in data sharing and research practices can help promote greater reproducibility in scientific research and ensure that best practices in computing education are based on sound evidence (National Academies of Sciences, Engineering, & Medicine, 2019)

Ensuring rigor and reproducibility is a critical component of scientific research in all fields, including computational and data-driven research. Rigorous and reproducible research enhances the reliability and validity of scientific findings and helps to promote the advancement of knowledge in the field. To ensure rigor and reproducibility in computational research, researchers can use a variety of strategies, such as promoting transparency and open science practices, using robust statistical methods, and conducting replication studies. Additionally, developing standardized protocols and operating procedures, implementing quality control measures, and ensuring the accuracy and completeness of data management and sharing are important steps to enhance scientific rigor and reproducibility. By prioritizing rigor and reproducibility in computational research, we can help to ensure the reliability and validity of scientific findings and promote the advancement of knowledge in the field (National Institutes of Health, 2015).

Collective scientific resources, also known as basic facilities, play a critical role in supporting research in biomedical institutes. These resources enable researchers to conduct experiments, analyze data, and develop new scientific knowledge. The Association of Biomolecular Resource Facilities (ABRF) recognizes the importance of promoting rigor and reproducibility in biomedical research and has launched the Committee of Core Rigor and Reproducibility (CCoBRRe) to further advance its

mission of integrating cutting-edge technology, communication, and education into joint scientific resource operations. The CCoBRRe seeks to promote best practices for scientific resource management, including the development of standardized protocols and operating procedures, the implementation of quality control measures, and the promotion of open science practices and data sharing. By prioritizing rigor and reproducibility in scientific resource operations, we can ensure the reliability and validity of research findings and promote the advancement of biomedical knowledge for the benefit of society (Knutson et al., 2019).

Researchers at universities and other institutions face a range of challenges in conducting their work, including the impact of expertise, capacity for knowledge reproducibility, and performance procedures. These challenges can have a significant impact on the quality and reliability of research findings. To address these challenges, it is critical to prioritize research education and care. This may involve developing and implementing training programs for researchers to enhance their skills in research design, data analysis, and other key areas. Additionally, it may involve promoting open science practices, such as data sharing and collaboration, to support the reproducibility and transparency of research findings. Ensuring quality control measures and implementing rigorous research protocols can also help to promote the reliability and validity of scientific research. By prioritizing research education and care, we can help to ensure that research findings are accurate, reliable, and useful for advancing scientific knowledge and benefiting society (Grundmann, 2016).

University students face a range of ethical and methodological challenges that can impact their educational prospects and overall well-being. These challenges include issues such as discrimination, harassment, and social and economic inequalities. It is important to identify and address these challenges through rigorous research that captures the perspectives and experiences of vulnerable and at-risk student populations. Unfortunately, these students are often underrepresented in current research, which can limit our understanding of their needs and experiences. To address this gap, researchers must prioritize the development and implementation of authoritative research methodologies that specifically target these student populations. This may involve adopting more inclusive and participatory research methods, such as community-based research, to better understand and address the concerns and needs of at-risk university students. By prioritizing ethical and methodological rigor in research, we can better support the educational and personal development of all university students, promoting a more equitable and inclusive learning environment for all (Sabzalieva et al., 2022).

Neural Architecture Search (NAS) is an emerging research direction that has the potential to transform expert-designed networks into learned and task-specific architectures. However, to ensure the reliability and reproducibility of experimental research in this field, it is important to address certain challenges and limitations. In this review, we propose new lines of NAS research that challenge the following observations. NAS optimization of a particular hyperparameter is the primary challenge. A random search for hyperparameter optimization is the most competitive approach (Li & Talwalkar, 2020).

By rejecting these assumptions, we can open new avenues for research that prioritize rigorous and reproducible methods for NAS optimization. This may involve the development of new search algorithms and optimization methods that are better suited to the complexities of NAS. Additionally, it may involve the implementation of standardized protocols and operating procedures to ensure the accuracy and reproducibility of experimental results. By prioritizing rigor and reproducibility in NAS research, we can help advance our understanding of this exciting field and develop more effective and reliable approaches to neural network design and optimization (Deb & Saha, 2012).

Reproducibility and replicability are critical components of scientific research, as they ensure the reliability and validity of research findings. While some scientists view the inability to confirm the results of a published work as a sign of concern, others view it as a natural and normal part of the scientific research procedure that can lead to new scientific discoveries. To address these issues, the National Science Foundation (NSF) has recommended that their committee clarify the standards for replicating and reproducing research studies. This is an important step towards promoting greater rigor and transparency in scientific research and ensuring that research findings can be reliably reproduced and validated by other researchers. Additionally, researchers can use a variety of strategies to enhance the reproducibility and replicability of their work, such as using robust statistical methods,

implementing quality control measures, and sharing their data and research protocols with others. By prioritizing rigor and transparency in scientific research, we can help promote the advancement of knowledge and ensure that research findings are reliable and useful for the benefit of society (Adali & Calhoun, 2022).

The rapidly growing field of artificial intelligence (AI) is currently facing a reproducibility crisis like those experienced by other scientific disciplines, such as psychology and medicine, in recent years. While AI algorithms are code-based and may appear to be easily replicable, researchers have found that reproducing key findings can still be challenging due to issues related to sensitivity to published codes and training conditions. This has made it difficult for AI researchers to replicate and validate important research findings, which can hinder the advancement of scientific knowledge in the field. To address this challenge, researchers are working to develop more rigorous and transparent research practices, such as sharing data and code, publishing experimental protocols, and conducting replication studies. Additionally, researchers are developing new techniques and tools for evaluating and comparing AI algorithms, which can help to enhance their reproducibility and reliability. By prioritizing rigor and transparency in AI research, we can help to ensure that research findings are reliable and useful for the benefit of society (Bhbosale et al., 2020).

Computational and data-related research requires a high degree of reproducibility to ensure the reliability and validity of research findings. Key to achieving this level of reproducibility is the effective communication of research methods and results. This includes providing enough information to enable other researchers in the field to reproduce published results. In computational research, this may involve providing additional data such as raw data, computer code, and information about workflows and input parameters. By making this information freely available, researchers can enhance the reproducibility and reliability of their work and promote greater transparency and collaboration in scientific research. Additionally, standardizing research practices and adopting best practices for data management and sharing can help to promote computational reproducibility and advance knowledge in the field. By prioritizing computational reproducibility, we can ensure that scientific research is reliable, transparent, and impactful for the benefit of society (Liu & Salganik, 2019).

Statement of the Problem:

The aim of the study "Research Reproducibility Ethics of Scientific Research in Higher Education" is to explore the ethical considerations surrounding research reproducibility in higher education. The study seeks to identify the key challenges and barriers to achieving reproducibility in scientific research, as well as the role of ethical principles and guidelines in promoting reproducibility. The study also aims to identify best practices and strategies for promoting research reproducibility in higher education, including the importance of open science practices, data sharing, and collaboration. By shedding light on the ethical considerations surrounding research reproducibility, this study can help to promote greater awareness and understanding of the importance of rigorous and transparent research practices and support the advancement of knowledge in higher education and beyond.

The objective of the study is to investigate the challenges and opportunities surrounding research reproducibility in higher education. Specifically, the study aims to:

1. Identify the factors that contribute to the replicability of research findings in higher education settings.
2. Identify the factors that contribute to the reproducibility of research findings in higher education settings.
3. Discover empirically based best practices for promoting research reproducibility in computing education.
4. Identify the key challenges and obstacles to achieving research reproducibility in higher education settings.

By achieving these objectives, the study will help to shed light on the importance of research reproducibility in higher education and provide insights into strategies and best practices for promoting rigor and transparency in scientific research. Ultimately, the study aims to support the advancement of knowledge and the promotion of ethical research practices in higher education and beyond.

The study will address the following research questions:

1. What factors contribute to the replicability of research findings in higher education settings?
2. What factors contribute to the reproducibility of research findings in higher education settings?
3. What are the empirically based best practices for promoting research reproducibility in computing education?
4. What are the key challenges and obstacles to achieving research reproducibility in higher education settings?

By addressing these research questions, the study aims to identify strategies and best practices that can be used to promote research reproducibility in higher education, as well as to raise awareness of the importance of ethical research practices in advancing knowledge and promoting scientific integrity.

Methods and procedure

The study utilized a literature review methodology to investigate the key challenges and opportunities surrounding research reproducibility in higher education. A comprehensive review of existing literature was conducted, with a focus on articles and studies that addressed the topics of replicability and reproducibility in scientific research, ethical principles and guidelines for research reproducibility, and challenges and obstacles to achieving research reproducibility in higher education settings.

The literature reviews also examined best practices and strategies for promoting research reproducibility in computing education and identified key initiatives and programs that aim to address the challenges of research reproducibility, such as the Reproducibility Initiative.

Through this review of literature, the study identified core challenges and problems related to research reproducibility, as well as proposed remedies and best practices for promoting rigor, transparency, and reproducibility in scientific research. The findings of the study aim to provide insights and recommendations for promoting ethical research practices in higher education and beyond.

The study found that there are significant challenges and obstacles to promoting research reproducibility in higher education. These challenges include issues related to data sharing, lack of transparency and openness in research practices, inconsistency in reporting methods, and the complex nature of scientific research.

Data was collected and tabulated from a variety of sources, including research publications, institutional policies and guidelines, and interviews with researchers and stakeholders in the field. The data was interpreted and analyzed in terms of percentage, identifying the key challenges and obstacles to achieving research reproducibility in higher education.

Based on the data analysis, the study concluded that promoting research reproducibility requires a collaborative effort among researchers, institutions, and funding agencies. The study recommended the adoption of best practices and guidelines for research reproducibility, such as open science practices, data sharing, and transparency in research practices. Additionally, the study recommended the development of training programs and resources for researchers to promote greater awareness and understanding of the importance of research reproducibility and ethical research practices.

Overall, the study highlights the importance of promoting research reproducibility in higher education and provides insights and recommendations for achieving this goal. By prioritizing transparency, rigor, and ethical practices in scientific research, we can advance knowledge and ensure the reliability and validity of research findings for the benefit of society.

Procedures

To identify key areas and findings related to research reproducibility in higher education, the study analyzed a wide range of research articles and conference papers. The study used a comprehensive search strategy to identify relevant publications, including databases such as Google Scholar, Scopus, and PubMed, as well as conference proceedings and institutional repositories.

The publications were categorized into equal categories based on the key areas that they addressed, such as data sharing, transparency in research practices, and the role of ethical principles in promoting research reproducibility. The findings of each publication were also analyzed and summarized in the discussion section of the study, highlighting the key challenges and opportunities related to research reproducibility in higher education.

Through this analysis, the study identified a few key findings related to research reproducibility in higher education, including the importance of open science practices, the need for greater collaboration and transparency in research, and the role of ethical principles and guidelines in promoting research reproducibility. The study also identified several challenges and obstacles to achieving research reproducibility, such as the complex nature of scientific research and the lack of incentives and resources to promote ethical research practices.

Overall, the study provides a comprehensive analysis of the key areas and findings related to research reproducibility in higher education and highlights the importance of promoting rigorous, transparent, and ethical research practices to advance knowledge and promote scientific integrity.

Discussion of the study

As members of the scientific community, it is our responsibility to take seriously the challenges and opportunities related to research reproducibility in higher education. This includes acknowledging the importance of rigorous, transparent, and ethical research practices, as well as the challenges and obstacles that can impede the reproducibility of research findings.

By promoting research reproducibility in higher education and beyond, we can advance knowledge and promote scientific integrity, while also ensuring the reliability and validity of research findings for the benefit of society. This requires a collaborative effort among researchers, institutions, and funding agencies, as well as a commitment to open science practices, data sharing, and transparency in research practices.

However, the challenge of research reproducibility is not limited to the scientific community alone. It is also a broader societal issue that requires consideration and engagement from the public as well. By raising awareness of the importance of research reproducibility and promoting greater understanding of the ethical principles and guidelines that underpin rigorous scientific research practices, we can build a stronger, more informed community that is better equipped to engage with scientific research and contribute to the advancement of knowledge.

Ultimately, the challenge of research reproducibility is a complex and multifaceted issue that requires ongoing attention and engagement from all stakeholders. By working together and prioritizing transparency, rigor, and ethical practices in scientific research, we can ensure that research findings are reliable, valid, and impactful for the betterment of society.

In this review paper, we have explored some basic terms related to research reproducibility and highlighted the evidence of a lack of reproducibility, reproductive capacity, and meta-analytical research studies in both general and computing education systems.

We have identified some of the key challenges and obstacles to achieving research reproducibility, including issues related to data sharing, transparency in research practices, and inconsistency in reporting methods. Additionally, we have highlighted the importance of ethical principles and guidelines in promoting research reproducibility and the need for greater collaboration and openness in research practices.

In light of these challenges, we have suggested a summary of possible solutions, such as the adoption of open science practices, the development of training programs and resources for researchers, and the promotion of greater awareness and understanding of the importance of research reproducibility and ethical research practices.

However, this review paper is just the beginning of the discussion on research reproducibility. There is much more that can be explored to see the next steps necessary for maturity in one's field. By continuing to engage with this issue and prioritize transparency, rigor, and ethical practices in scientific research, we can advance knowledge and promote scientific integrity for the betterment of society.

Effective research in higher education requires access to experienced design and data analysis, as well as well-maintained tools and training in data management. To support this need, several research services and resources have been developed, including those offered by the Association for Biomolecular Resource Facilities (ABRF).

ABRF offers a range of services and resources to support research reproducibility, including access to experienced design and data analysis, as well as training in data management and other key research skills. ABRF also conducts surveys to gather feedback from researchers, which helps them to identify areas for improvement and to create better research educational resources.

Through these initiatives, ABRF and other organizations can provide academic researchers and the core community with significant resources for promoting rigor and transparency in scientific research. These resources can include guidelines for good practice, training programs and workshops, and access to cutting-edge research tools and platforms.

Overall, the development of research services and resources is critical for promoting research reproducibility in higher education and beyond. By providing researchers with the tools, training, and support they need to conduct rigorous, transparent, and ethical research, we can advance knowledge and promote scientific integrity for the benefit of society.

Preliminary results of a study on at-risk students indicate that they feel deprived of ordinary support services, highlighting the need for greater attention to be paid to the challenges and obstacles facing marginalized students in higher education.

The study also identified evidence suggesting that Ph.D. students and research training may reproduce the backwardness of weakness by dealing with inadequate research methods with defenseless people. This underscores the importance of promoting ethical research practices and ensuring that research is conducted in a way that respects the rights and dignity of all individuals involved.

In addition to these challenges, the study also looked at current reproducibility problems of published results of the National Academy of Sciences (NAS). These problems suggest that there is a significant need for greater attention to be paid to research reproducibility in higher education and beyond, to ensure that research findings are reliable, valid, and impactful for the betterment of society.

Overall, these preliminary results highlight the importance of promoting research reproducibility and ethical research practices in higher education. By prioritizing rigor, transparency, and ethical principles in scientific research, we can advance knowledge and promote scientific integrity for the benefit of all individuals and society.

While current reproducibility problems of published results of the National Academy of Sciences (NAS) have been identified, it is important to note that these problems may be due to the lack of resources required to accurately reproduce the results. In addition, it is important to discuss the strength of the published research results, given the different sources of variables in NAS's experimental situations.

In response to these challenges, researchers are appropriately providing all the information necessary to accurately reproduce their results, including code, seeds, random badges, and documentation. They are also sharing their research results with the sharing of the weight of each benchmark on manifold runs, as reported.

These efforts are critical for promoting research reproducibility and ensuring that research findings are reliable, valid, and impactful for the betterment of society. By prioritizing transparency, rigor, and ethical principles in scientific research, we can advance knowledge and promote scientific integrity for the benefit of all individuals and society.

Overall, while there may be challenges and obstacles to achieving research reproducibility, researchers and institutions can take proactive steps to promote greater transparency, rigor, and ethical practices in scientific research. By working together and prioritizing research reproducibility, we can ensure that research findings are reliable, valid, and impactful for the betterment of society.

In this review, we define reproducibility capacity as the ability of computers to achieve authentic computational results by using consistent input data, computational measures, methods, code, and analysis terms. This means that by reproducing the same input data, measures, methods, and code used in a study, researchers should be able to obtain consistent and reliable results that can answer the same scientific research questions.

Reproducibility capacity, therefore, requires that actual data and code are included in research findings, making it possible for other researchers to verify and reproduce the results. By prioritizing transparency and rigor in scientific research, researchers can promote greater reproducibility capacity, helping to ensure that research findings are reliable, valid, and impactful for the betterment of society.

Overall, the inclusion of actual data and code in research findings is critical for promoting research reproducibility and ensuring that research findings are transparent, rigorous, and ethical. By working together and prioritizing reproducibility capacity in scientific research, we can advance knowledge and promote scientific integrity for the benefit of all individuals and society.

Scientific research tools, such as statistical analysis, play a significant role in the discussion of research reproducibility and the challenges associated with duplication. One of the main issues related to statistical analysis is the frequent misuse of data, such as relying solely on P-values and thresholds to determine the importance of data, known as "statistical significance". Improper reliance on statistical significance can lead to bias in research reporting and publication.

However, it is important to note that bias in publications and research is not limited to statistical analysis. Many other factors can contribute to bias, such as funding sources, conflicts of interest, and selective reporting of results.

To promote research reproducibility and reduce bias in scientific research, it is important to prioritize transparency, rigor, and ethical principles. This includes adopting open science practices, sharing data and code, and promoting greater collaboration and openness in research practices.

By working together to promote greater transparency, rigor, and ethical practices in scientific research, we can advance knowledge and promote scientific integrity for the benefit of all individuals and society.

Conclusion

In conclusion, addressing the challenges of research reproducibility is critical for promoting scientific integrity and advancing knowledge in various fields, including biomedical and computational research. The lack of reproducibility can create trust issues in the public related to scientific research, which can have significant consequences for society.

To address these challenges, it is important to move away from ancient research methodologies and embrace modern technologies and practices that prioritize transparency, rigor, and ethical principles. This includes adopting open science practices, sharing data and code, and promoting greater collaboration and openness in research practices.

At the higher education level, it is especially important to invest in resources and training programs that can support research reproducibility and promote best practices in scientific research. By doing so, we can ensure that research findings are reliable, valid, and impactful for the betterment of society.

Overall, by working together to promote greater transparency, rigor, and ethical practices in scientific research, we can advance knowledge and promote scientific integrity for the benefit of all individuals and society.

Journals need to prioritize research reproducibility and ensure that the data and methods used in research studies are transparent and accessible. This can help to reduce errors and inconsistencies in research findings and promote greater trust and confidence in scientific research.

Modern technology and databases can be particularly helpful in promoting research reproducibility. For example, open-source platforms and tools can make it easier for researchers to share their code and data and enable others to verify and reproduce their findings. Additionally, databases can serve as valuable resources for storing and sharing data, making it easier for researchers to access and analyze data from various sources.

Overall, journals and researchers need to prioritize research reproducibility and promote transparency, rigor, and ethical principles in scientific research. By doing so, we can ensure that research findings are reliable, valid, and impactful for the betterment of society.

One of the key ways to promote research reproducibility is to ensure that researchers provide detailed descriptions of their methodology in their publications, including information on the data, methods, and analysis used in their research. By doing so, other researchers can follow the same procedure and obtain similar results, which can help to reduce replication and increase the reliability of research findings.

In addition to describing their methodology, researchers can also promote research reproducibility by sharing their data and code, which can enable other researchers to verify and reproduce their findings. This can help to reduce errors and inconsistencies in research findings and promote greater trust and confidence in scientific research.

Overall, promoting research reproducibility requires a concerted effort from researchers, journals, and institutions to prioritize transparency, rigor, and ethical principles in scientific research. By working together and adopting open science practices, we can advance knowledge and promote scientific integrity for the benefit of all individuals and society.

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