Towards research integrity implementation in biomedical research : Research integrity practices in biomedicine versus other disciplinary fields

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UNIVERSITY OF SPLIT
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CONTENT

LIST OF ABBREVIATIONS AND ACRONYMS

ALLEA	All European Academies
ANR	National Research Agency (France)
COPE	Committee on Publication Ethics
CORDIS	Community Research and Development Information Service
COREQ	Consolidated Criteria for Reporting Qualitative Research
CROSBI	Croatian Scientific Bibliography
CSIC	Spanish National Research Council
DRP	Detrimental Research Practices
ENRIO	European Network Of Research Integrity Offices
ENTIRE	Mapping Normative Frameworks for Ethics and Integrity of Research
ERC	European Research Council
EU	European Union
EUREC	European Network of Research Ethics Committees
FFP	Fabrication, Falsification, and Plagiarism
FWF	Austrian Science Fund
GDPR	General Data Protection Regulation
GRU	National Commission for Investigation of Research Misconduct (Norway)
IRB	Institutional Review Board
JBI	Joanna Briggs Institute
LARI	Luxembourg Agency for Research Integrity
LERU	League of European Research Universities
MLE	Mutual Learning Exercises
MOOC	Massive Open Online Courses
NASEM	National Academies of Sciences, Engineering, and Medicine
NEM	National Committee for Medical and Health Research Ethics
NENT	National Commission for Research Ethics in Science and Technology (Norway)
NESH	National Committee for Research Ethics in the Social Sciences and Humanities
OA	Open Access

ORI	Office of Research Integrity (USA)
PRINTEGER	Promoting Integrity as and Integral Dimension of Excellence in Research
PRISMA-ScR	Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews
QRP	Questionable Research Practices
RCR	Responsible Conduct of Research
RE	Research Ethics
REC	Research Ethics Committee
RFO	Research Funding Organization
RI	Research Integrity
RIA	Research Integrity Advisor
RIOs	Research Integrity Offices/Officers
RPO	Research Performing Organization
SOP	Standard Operating Procedure
SOPs4RI	Standard Operating Procedures for Research Integrity
TENK	Finnish Advisory Board on Research Integrity
UK	United Kingdom
US	Unites States
WCRI	World Conferences on Research Integrity
WOS	Web of Science

1. INTRODUCTION

1.1. An overview of research integrity definitions and concepts

Research integrity (RI) is of tremendous importance for science since future research endeavors rely on the reliability and trustworthiness of previous research studies. RI started to get more attention within the research community in the late 80s and 90s when first efforts to promote responsible research became a point of interest among scientists (1–3). These efforts emerged as a product of concerns within the research community when cases of alleged research malpractices were brought to light, especially in biomedicine (3). The cases of alleged falsification and fabrication of immunology and vaccine data were a driving force and a wakeup call for the research community to start developing RI standards and guidance to help researchers stay on the path of responsible research conduct (4–7). One of the earliest cases to receive significant public attention was that of falsified data on autism and vaccines (5, 7). The Wakefield autism study, and other biomedical cases, such as the Macchiarini case, or Wo-suk stem cell research showed how fraudulent biomedical research could have immediate consequences for humans (5, 8, 9). However, besides biomedicine which seemed to be mostly affected by misconduct cases, based on the number of perpetrators (10), other disciplines were also not exempt from fraudulent research (11). The case of noted Dutch researcher Diedrick Stapel shook the world of psychology and academia when it was discovered that about a decade of work and research papers on racial stereotyping and hypocrisy was fraudulent (12, 13). Further, computer scientists from the University of Kansas were found to have plagiarized much of their research, as well as several prominent philosophy and communication researchers (11, 14–16). Another instance of academic fraud that gained significant media attention was the case of Japanese archeologist, who was found to have falsified discoveries (17, 18). These are just a few examples from a long list of cases of research misconduct that have occurred in various disciplines, demonstrating that efforts to promote RI and combat research misconduct are global endeavors. The cases that have been brought to light may indicate only a small proportion of all the research misconduct incidents that remain undiscovered. How much damage has been done to science? We are yet to find it out. A large-scale survey of researchers from various disciplines in the United States showed that as many as 33% of researchers admitted to being involved in some research misbehavior at least once in their research career (19). A systematic review and

meta-analysis of anonymous surveys that focused on researchers who committed plagiarism found that substantial number of them had engaged in plagiarism at least once in their career (20). Moreover, a study on research misconduct in the Croatian scientific community showed that Croatian scientists are no exception, as many researchers reported being involved in some sort of research misbehavior (21). The newest study, a large-scale survey conducted with almost 50 000 researchers, showed that misconduct happens today, regardless of the discipline researchers work in (22).

To combat research misconduct as a first line of defense and to help researchers avoid further malpractices, universities, research institutes, other research organizations, and professional societies started developing RI guidance documents and developed processes for the examination of their quality in helping researchers to tackle the issues of research misbehavior already in the 90s (23). Further, the establishment of RI bodies, such as the Office of Scientific Integrity Review as a part of the USA National Institute of Health or later initiatives like the USA Office of Research Integrity (2, 3), and realization of the importance of RI education and employment of preventative approaches focused on researchers were introduced for further combating research malpractices. Besides practical guidance, the research community recognized the need for setting standards in the RI field, which included the clarification in terms of what constitutes research misconduct and RI, how RI differs from research ethics (RE) – a concept familiar since World War II and Nuremberg trials (24–26), and how it connects to the responsible conduct of research (RCR) – a term often used as a synonym for RI (2, 27). Throughout the years and RI literature, numerous efforts and authors have provided definitions for these terms. Among many, Steneck, in his work "Fostering Integrity in Research: Definitions, Current Knowledge, and Future Decisions" (2), provides a conceptual clarification of terms that this study follows.

According to Steneck, RI and RE are interrelated but different concepts that involve different perspectives and approaches to research and stakeholders included in the research process. While RE includes behavior and actions underpinned by morality, RI focuses on professional standards defined by the research community, disciplines, and organizations. However, it is evident that both have elements of one another as RE also has set and defined standards in conducting research with, for example, human or animal research participants (28, 29). Similarly, RI involves moral reasoning from scientists regarding how thorough and honest

they are doing their work. RI rules, embedded in, for example, organizational policy guidance, are part of the deontological requirements of researchers (30). Moreover, both RI and RE rely on principles such as respect, care, fairness, honesty, accountability, and beneficence toward the research community, research participants, and society. RI is also integral to researchers' moral obligation to be honest and responsible. In addition, although having slightly different stakeholders involved with the ethical or integrity processes and questions (e.g., for RE research ethics committees and RI research integrity officers), both RI and RE address questions that do involve the same stakeholders – researchers, research organizations, funders, and publishers (2). DuBois and Antes, in their work "Five dimensions of research ethics", perfectly describe this relationship between RI and RE by saying that it is not possible to maintain personal integrity without demonstrating it through ethical behavior, and without personal integrity, it is unlikely that ethical behavior will be consistent (31). However, having separate policies, processes, and bodies for handling specific RI and RE issues in today's constantly growing and progressing research environment is deemed necessary for the adequate promotion and implementation of RI and RE standards and provides a better overview and control of RI and RE malpractices (32, 33). Another term requires clarification to understand the RI field fully. The RCR is usually used as an umbrella term for RI and RE. RCR is, by Steneck, "simply conducting research in ways that fulfill the professional responsibilities of researchers…" meaning both their moral and professional responsibilities entailed in RE and RI (2). However, it is important to mention that today RI and RCR are often used as synonyms, and it is often a geographical matter. For example, in some countries, such as the USA and Australia, RCR is the used term, while in Europe, RI is more widespread (2, 34–36). Because of this, in this study, the terms RI and RCR are used interchangeably, and the distinction between them is not made in terms of inclusion criteria and analysis (e.g., in the scoping reviews). On the other hand, this study does distinguish between RI and RE and recognizes them as two related but different concepts, as defined by Steneck.

Defining what constitutes research misconduct – the ultimate poor research behavior, standing on the opposite side of good research practices – is also essential for the RI field. The Responsible Science report from 1992 defined research misconduct as fabrication, falsification, and plagiarism (FFP) (1, 3). Fabrication is considered to be making up data or results; falsification is to manipulate research materials, equipment, and processes; and plagiarism is to

take others' ideas without giving appropriate credit. Later publications that play an important role in the RI field, like Steneck's work "Fostering Integrity in Research: Definitions, Current Knowledge, and Future Decisions", the National Academies of Sciences, Engineering, and Medicine 2017 book "Fostering Integrity in Research" (often used as a framework for self-regulation of RI in the US), and the ALLEA European Code of Conduct for Research Integrity provided the same definitions (2, 3, 37). However, considering the number of currently existing guidance documents on research misconduct and RI (evident from the scoping review that is a part of this study) and their geographical and disciplinary origin, we still may find a slight difference in what fits into research misconduct. A Martinson et al. study from 2005 suggested that FFP definitions are too narrow and they should also capture other behavior, such as not respecting ethical norms and rules in experimentation with human subjects, inadequate record keeping, and failure to disclose conflict of interest (19). A 2015 study from Resnik at al. showed that many national RI policies, although recognizing FFP as the core of research misconduct, include behaviors such as unethical authorship or publication practices and conflict of interest in the definitions of misconduct (38). In most cases, the three deadly sins of FFP stand today as a definition of what constitutes severe breaches of RI (39). However, in some cases, definitions are broader and extend to the behavior of so-called questionable or detrimental research practices or other unethical behaviors not strictly linked to research practices, such as, for example, gender or ethnic inclusivity in the research environment (39–41). While slight deviations in the broadness of the definition of research misconduct do exist, fabrication, falsification, and plagiarism are universally accepted as severe forms of research misconduct, which is also a standard followed in this study.

While the FFP is well defined, as described above, more ambiguity and heated debates regarding definitions exist in the area of questionable research practices (QRP), also often referred to as detrimental research practices (DRP) or other unacceptable research practices (42). For example, European Code of Conduct for RI recognizes "other unacceptable practices" (37), National Academies of Sciences, Engineering, and Medicine guidance Fostering Integrity in Research calls them "detrimental research practices" (2), while the Netherlands Code of Conduct and many other guidance documents, as well as scientific literature in the RI field, call them "questionable research practices" (43). Besides the lack of consensus on terminology, there is also no consensus on what these practices are, i.e., what behavior is this

questionable/detrimental/unacceptable practice. The examination of the existing literature dealing with questionable/detrimental/unacceptable practices shows that they usually involve poor authorship practices, poor research data management, poor supervision, and conflict of research interest (38, 44, 45). Regardless of being the gray zone of the RI field and lacking ubiquitous definitions, the scientific community recognized the detrimental effect of these practices and their potential to corrupt science, compromise research participants' safety, and lead to a loss of public trust in science. Moreover, research shows that researchers' engagement in these practices exceeds FFP and is around 30% (compared to FFP, which is estimated to be around 2%) (2, 19, 46, 47). Why? While the majority of researchers are well familiar with FFP (47), these "smaller" detrimental research practices are less in the spotlight, or less known to researchers, and less defined (same as the sanctions for researchers involved in some of these practices), which leads to them occurring more often. While detrimental research practices may not have a substantial individual impact or public attention, like the occurrence of one of the FFP, collectively, these practices contribute to untrustworthy science and research biases (48). Because of the detrimental consequences for science, in this study, from this point on, the term "detrimental research practices (DRP)" is used when referring to them.

1.2. Research integrity and contemporary challenges

Some of the most prominent challenges in the modern era of RI were already mentioned in the previous section – issues related to the standardization of central concepts and definitions and the existence and regular occurrence of detrimental research practices. However, these are just an apple in a barrel of issues related to RI that exist today. However, before going into details about contemporary issues and challenges, this section will first highlight several positive RI initiatives that have changed the research community since the RI field was established in the early 90s.

1.2.1. Initiatives for promoting research integrity

RI evolved, and together with it, researchers and the scientific community evolved to be more reliable and trustworthy in their research endeavors. The development and implementation of RI guidance documents are often recognized as significant change drivers in promoting good research behavior and avoiding research misconduct and other detrimental research practices. Research organizations and other research-involved stakeholders have developed RI guidance

documents to help researchers stay on the path of integrity. These guidance documents typically tend to define acceptable and unacceptable research behavior, actions in cases of research misconduct, and roles and responsibilities of various stakeholders involved in the research process (30). One of the essential global initiatives in terms of guidance documents that set standards in the field was the Singapore Statement on Research Integrity (49). Although quite broad and inspirational guidance on RI, the Singapore Statement was just the beginning of progress in developing and setting standards for researchers to conduct research with honesty, accountability, professional courtesy, fairness, and good stewardship. Today researchers have access to a library of global RI guidance documents that can guide them in planning, conducting, reporting, and reviewing research. Many of these documents are implemented within the research organizations' policies, and researchers must follow them. For example, the University of Split has recently implemented the European Code of Conduct for RI (50). Moreover, the European Code of Conduct for RI is implemented by the European Commission, another important research stakeholder, a funder, as a soft law for applicants for research grants (51).

The Singapore Statement was developed at the World Conferences on Research Integrity (WCRI) (52) as a global RI guidance. WCRI is an initiative of much importance for the development and promotion of RI that helps the RI field to evolve. Being held every two years, covering various topics from national-specific initiatives to global RI endeavors, the WCRI allows the RI community to continuously get together, discuss significant issues and address solutions for current challenges. Besides guidance for individual researchers, this event brought to life initiatives and guidance documents aimed at other research stakeholders, such as research organizations and funders, who play an important role in how much researchers follow and adhere to RI guidance. WCRI recognized that researchers are not the sole actors when it comes to RI. Researchers, research organizations, funding organizations, and scientific publishers must work together to allow systemic changes and better implementation of RI standards in practice. Some of the additional important global RI guidance brought in the WCRI is the Montreal Statement on RI in Cross-Boundary Research Collaborations from the 3rd WCRI that brought together the responsibilities of individual and institutional stakeholders in collaborative research endeavors (53). More recently, the Hong Kong Principles for RI, brought during the 6th WCRI, highlighted the importance of making changes in how researchers are evaluated by research organizations and funders for their work in order to avoid the infamous publish or perish policy

and perverse incentives systems (54). The most recent, 7th WCRI, has prepared a Cape Town Statement focused on equity and fairness of resources in research (55).

Embedded also in the previously mentioned WCRI initiatives, especially the Hong Kong Principles focused on the evaluation of research (which includes also putting more emphasis on data sharing and openness of research), the modern RI environment is recognizing and promoting the value of open science initiatives (54). Open access publications, open peer review and access to research data, or simply more transparency in disseminating research output are today considered a cornerstone of better research and a way of fighting research misconduct and other detrimental research practices (56). Developing an open science mindset became a focal point in biomedical research during the COVID-19 pandemic when open science initiatives were shown to be the accelerators of biomedical research (57). Regardless of the disciplinary field, open science is embedded in almost every research today, as many funders mandate. In Europe, the European Commission mandates in its grant agreements the openness of research funded by its public money, and in the US, the government brought a policy to make all publicly funded research open access upon publication (58). The FAIRness (making data findable, accessible, interoperable, and reusable) of the research publications, data, and software is considered by many funders and research organizations as an important contribution of researchers to more accessible and trustworthy research (59). All this is closely related to the integrity of research as openness contributes to the efficiency and quality of research, and better verification and validation of research helps correct errors and avoid research misconduct in disseminated research (60).

The shift of spotlight from individual researchers to other stakeholders mentioned briefly in the description of WCRI initiatives is a huge difference between the past and present of RI. Throughout history, research misconduct and RI have been looked through the prism of the individual researcher (3, 61, 62). Researchers were considered to have a set of personal moral and ethical values and personality characteristics that may lead to deviations in behavior (63). In search of explanations on why research misconduct happened and how to avoid it in future research, an individualistic approach was used. Personality factors, especially the dark triad of personality – narcissism, psychopathy, and Machiavellianism were often sought as primary reasons why researchers are involved in research misconduct (48, 61, 64–66). Similarly, in the past, most of the initiatives aiming at promoting RI and preventing research misconduct, like RI

training and RI guidance documents, were focused on individual researchers (3, 48). Although science is made of individuals who do make mistakes in their work because of a lack of knowledge, personality traits that make them more susceptible to committing misconduct, and other factors, science is not made only of individuals and how the research is conducted is often not determined by only individuals' behavior but rather the research culture they operate in (67–71). Thus, recent RI endeavors to promote and implement RI have moved towards a system approach, in which individual researchers are only piece of the puzzle in successful RI promotion and implementation. Each type of stakeholder has a set of responsibilities that contribute to the overall aim of promoting and implementing RI standards (72). Proper implementation of RI and adherence to good research practices implies the responsibility of researchers to conduct research following the guidance and standards provided by research performing and funding organizations. It includes the responsibility of these organizations to implement policies on good research practices, provide adequate education and training, have mechanisms in place that will deal with breaches of RI, and foster an organizational culture of integrity through open communication, dialog, inclusiveness, support, and fair incentive system. The study by Mejlgaard et al. listed the three main areas (support, organization, and communication) related to nine topics (research environment, supervision and mentoring, integrity training, ethics structures, integrity breaches, data practices, and management, research collaboration, declaration of interest, publication, and communications) (73). The initiatives, such as the Bonn PRINTEGER Statement and Canadian Try-Agency Framework on Responsible Conduct of Research (RCR) outline research organizations' responsibilities in promoting RI and RCR and creating strong integrity culture, providing support for researchers by raising awareness and offering education on RI issues, as well as in establishing RI structures and processes for handling allegations of misconduct (74, 75). At the same time, research funding organizations play a major role in shaping the behavior of both individual researchers and research organizations. Their contribution to RI is visible through the alignment of funding policies with requirements to RI standards (3, 76, 77). Last but not least, scientific publishers and journals have the responsibility and are accountable for recognizing the mistakes in research and undertaking steps that will ensure that only trustworthy and high-quality scientific knowledge is disseminated (78, 79).

1.2.2. Main challenges to research integrity

After outlining some prominent initiatives that helped evolve RI into an essential aspect of research, it is important to outline the issues that still need to be resolved. In the following sections, the focus will be on the issues that are related to the context and the content of this thesis – RI frameworks, RI guidance documents, and factors influencing the promotion and implementation of RI on different levels (i.e., level of individual researchers, research organizations, and the system of science).

Structures for and practices of RI (frameworks) differ among countries. Research shows that approaches to RI, although usually coupled with a shared comprehension of fundamental values and norms related to responsible research, often differ between countries (32, 80–82). Although contextual divergences related to the country's legal context are essential regarding RI, a level of harmonization is required so that research communities can equally approach RI issues (83–85). As research is continuously developing, many researchers are in constant pursuit of new challenges and new collaborations. This often leads to a change of place of work, i.e., country of work of researchers, which faces researchers with sometimes wholly different and often incompatible approaches to RI. If we consider that research is a global endeavor, and researchers are building future knowledge on the existing knowledge, regardless of which country the knowledge comes from, it is not strange to expect a certain level of harmonization of the RI standards. Creating a certain level of harmonized RI frameworks is important for the future development of RI. The harmonization could help minimize risks of countries duplicating RI efforts and hence wasting resources, as well as avoiding potentially incompatible guidance is promoted, especially when it comes to how to resolve cases of research misconduct (30, 86). The current lack of harmonization and existing heterogeneity when it comes to RI is seen in various RI structures established across countries to deal with RI issues and research misconduct. Moreover, the lack of harmonization is seen in approaches to handling RI malpractices and research misconduct investigations, national legal policies and processes for promoting RI and preventing research misconduct, and existing national initiatives for promoting RI within the research community and among the general public (32, 87). While some countries have established national bodies designated for RI issues (e.g., RI committees or agencies) or mandate research organizations to establish these bodies at the institutional level (e.g., RI offices and officers), some countries are still having difficulties to even distinguishing

RI bodies from RE ones, such as RE committees (30, 32). Besides these structures, approaches to handling research misconduct cases vary. Further, while some countries have developed detailed procedures for investigations and protection of whistleblowers, in others, the investigations are still the primary responsibility of research organizations which often leaves space for sweeping bad things under the rug to preserve a good reputation (88, 89).

As mentioned previously, RI guidance documents are often used to enhance RI promotion and implementation among individual researchers and research organizations. However, studies show that despite the value of RI guidance documents and the progress in the development of RI guidance documents that will be tailored to the researchers' needs (e.g., disciplinary or research specifics), there is still a gap between the number of existing guidance documents and the effectiveness in preventing research misconduct and detrimental research practices (90, 91). While research organizations mostly have RI guidance in place, many of which are mandatory for researchers working and conducting research in specific organizations, the guidance documents are not always complied with (90). A product of the lack of compliance is emerging cases of research misconduct or detrimental research practices. Analysis of retracted articles in PubMed showed that in a span of 8 years (from 2012 to 2020), there were 2047 retracted articles due to some misconduct or detrimental practice in the research and similar research brought similar findings (92–96). However, not all identified behavior is committed with the element of intention, and some of the mistakes in retracted articles could be due to the honest mistake or lack of knowledge or appropriate guidance (94). Nevertheless, the suboptimal guidance documents could also explain the occurrence of detrimental research practices or mistakes in research. Today, guidance documents come in many forms, and their content varies even more, creating confusion for researchers, especially in collaborative research efforts (48, 96, 97). While some guidance documents focus on positive approaches, i.e., promoting good research practices, others focus on definitions of research misconduct and detrimental research practices (98, 99). Moreover, some guidance documents are more focused on research values and are more broad and aspirational in guiding research on the path to integrity. On the other hand, existing norm-based or normative guidance documents focus on providing explicit guidance on certain RI practices and behavior, which is embedded in certain situations, times, and places (98). The types of guidance documents are various as well. Today in the RI field, we have codes of conduct, guidelines, checklists, flowcharts, and newly introduced standard

operating procedures (SOPs), all having different formats for presenting guidance on RI. If we delve deeper into the content or provided guidance, i.e., definitions or steps to be taken described in these guidance documents, we will witness even more discrepancies and divergences in the mere content of the guidance documents (100, 101, 102). When disciplinary and research specifics are considered, the heterogeneity of guidance documents could be even more pronounced (103). Although the basis of good behavior and definitions of research misconduct is the same for all, each disciplinary field has its practices and standards, for example, for data management or authorship, and perhaps preferences on how concrete guidance should be in addressing RI issues. In biomedical research, where quality assurance and quality control systems are essential in the work of every research laboratory, as well as in clinical trials where step by step procedures, like for example SOPs, are used to minimize the mistakes in conduct and prevent serious damages and risks for research subjects a more detailed oriented or step by step procedures for RI could as well be a preference (104, 105). On the other hand, in disciplines where research is more theoretical, whether it is theoretical mathematics or physics from natural sciences, philosophy and ethics from social sciences, or history from humanities, it could be preferable to have explicit definitions of what is falsification, fabrication, and plagiarism, paired with aspirational and theoretical guidance on how to avoid these in conducting and writing research (106–109). Moreover, the inclusion of various stakeholders in research also requires various and research-role-specific guidance to provide results in practice. The guidance for mentors and supervisors will, in some aspects, differ from those for PhD students, especially if we consider the mentioned disciplinary preferences and needs (110). So the main positive thing about RI guidance is that it exists in a large number; however the main issue remains – how to make the guidance more optimal and tailored to the researchers' needs in order to enhance the effectiveness of RI promotion and implementation and avoidance of research misconduct and detrimental research practices.

Besides developing optimal RI guidance that will be used by researchers and tailored to their needs, it is also important to have appropriate procedures and processes for implementing guidance documents. There is little use of written guidance if theoretical knowledge and advice cannot be transferred into practice and every-day research life (48, 111, 112). Many factors influence the promotion and implementation of RI and RI guidance documents. Regardless of the disciplinary field, RI promotion and implementation, as well as the implementation of RI

guidance documents, is influenced by factors that may have a positive or negative impact and are related to the level of individual researchers, research organizations, and the system of science. Today, this is one of the main recognized challenges within the RI community. Researchers' personality traits, poor relationships with mentors and educators, and lack of previous RI education and training are considered factors that may negatively influence researchers' adherence to the RI standards and guidance documents in their work (113–117). Moreover, researchers' behavior is often the product of the organizational research culture and structures and processes in the scientific system, whether functional or dysfunctional. How much research organizations invest or do not invest in RI promotion and education of researchers, as well as in preventing and sanctioning research misconduct and other detrimental research practices, plays a vital role in successful RI promotion and implementation (111, 118, 119). Taking into account an even bigger picture, the famous "publish or perish" or "perverse incentives" which permeate the research culture are one of the familiar factors of the dysfunctional research system that is focused more on the quantity of research rather than on the mere quality of conducted and published research (47, 120). As researchers' work is evaluated based on the number of publications and impact factors of the journals they published in, and their career perspectives career are dependent on these indicators, there is enormous pressure for researchers to publish more and in a tight schedule which leads to them being subject to unintentional mistakes or intentional malpractices in their work. This also leads to researchers' adhering less to the RI guidance documents and standards, which are in some cases also seen as an additional administrative burden to the already enormous amount of work that research requires. Incentives for publishing in high-impact factors journals are tempting as every researcher would most likely want to be globally recognized and cited for their work or receive additional funding and spread the network of collaborators.

As described above, issues related to RI frameworks, RI guidance documents, and factors influencing the promotion and implementation of RI have been explored across the scientific literature. Since the early development of RI as a field, and more intensively in the last decade, many hundreds of articles, reports, and other types of publications have been published on topics about national frameworks for RI, translating RI guidance documents into practice, how to avoid research misconduct, responsibilities of different research stakeholders, hyper competitiveness of research system, cases of frauds, detrimental research practices and

other issues that may have an impact on RI promotion and implementation. Interestingly, articles addressing these issues date from the 90s (121, 122) and the same issues are present today (123–126), which seems to indicate that the scientific community still does not have clear or definitive solutions on how to address these issues and make RI guidance documents more optimal, transfer written guidance successfully into practice, and establish frameworks that will foster the culture of integrity. This doctoral thesis aims to provide answers to these issues in biomedical research. The focus of this doctoral thesis, as explained in detail in the next section, is on RI guidance documents and how to improve their content characteristics and implementation depending on the biomedical disciplinary preferences in the context of general scientific framework. Regarding the guidance documents, the research in the doctoral thesis focused on SOPs as innovative RI guidance documents that could help improve and increase adherence to RI standards in biomedical research, in comparison to other research disciplines. Moreover, this doctoral thesis explores in detail what influences the promotion and implementation of RI and RI guidance documents in biomedicine and other research disciplines to optimize and operationalize processes to achieve better uptake of written guidance in practice. The RI frameworks existing throughout countries are also examined and present an important element that supports progress in RI in general.

2. RESEARCH AIM, HYPOTHESES, AND RESEARCH QUESTIONS

This doctoral thesis aims to obtain and synthesize information on the promotion and implementation of RI and RI guidance documents in biomedicine. The ultimate goal is to get a step closer to defining the optimal RI guidance and processes aimed at RI promotion and implementation in biomedicine by exploring the types and characteristics of guidance documents, factors influencing the implementation of RI and RI guidance documents on the level of individual researchers, organizations, and system of science, as well as national RI frameworks required for supporting the RI adherence.

In this study, three methodological approaches across four research studies were used. The first, comprehensive approach included the "landscaping" – mapping with the country report cards the real-life examples of how RI is promoted and implemented across European countries to obtain an overview of structures and processes essential for supporting RI culture (127). The second approach included the thorough examination of the existing literature and evidence in the format of scoping reviews to obtain a comprehensive overview of what is already known about the RI guidance documents and factors influencing the implementation of RI, as well as what are the main gaps that need to be addressed by further research, including this study (100, 128). Finally, the third methodological approach included a thorough examination of RI and RI guidance documents promotion and implementation and putting the text knowledge and landscapes into the practices through a qualitative approach, i.e., explorative semi-structured interviews with stakeholders of different backgrounds (105).

Before defining the aims of each research on which this doctoral thesis is based, a few clarifications are needed. First, it is important to emphasize that the four studies included in this thesis were conducted separately but together frame a comprehensive approach to exploring RI and RI guidance documents' development and implementation. Moreover, while the doctoral thesis is focused on biomedicine, the scoping reviews and interview study had a broader approach to the RI field and included in the analysis other disciplines as well. This is because these research studies were conducted as a part of the larger international project (Standard Operating Procedures for Research Integrity – SOPs4RI) (129) that aimed to explore RI issues across disciplines. However, additional analyses were conducted for this doctoral thesis to obtain input from the biomedical field and compare these findings with the findings from other disciplines.

Second, it is important to emphasize the difference between scoping and traditional literature reviews. Compared to traditional literature reviews, Scoping reviews are informed by the a priori protocol that describes the methodology to be employed, together with the thoroughly developed and defined search strategy for identifying relevant literature that will answer the predeveloped research question (130). Further, scoping reviews are conducted systematically, with several processes for ensuring robustness and the reproducibility of the studies and avoiding errors. Finally, scoping reviews ensure that data is extracted and synthesized in a structured way, usually with predefined items and concepts defined in the study protocol. Scoping reviews, by definition, do not offer a hypothesis, but rather their aim to collect available knowledge on a certain topic or research problem and identify gaps in knowledge to inform future research endeavors (130–132). Furthermore, qualitative studies do not offer a hypothesis as well. Empirical research in a qualitative format aims to explore in-depth a certain phenomenon and provide answers to specific research questions related to the phenomena (133). Last, and taking into consideration the previous explanations, instead of a hypothesis, this doctoral thesis aims at answering several questions, which are as follows:

1) What are the existing RI guidance documents available in biomedicine and other disciplines (natural sciences, social sciences, and humanities), and what are the main characteristics of these documents depending on the disciplinary origin?

2) What influences the promotion and implementation of RI and RI guidance documents in biomedicine in comparison to other disciplines?

3) What are the roles of different stakeholders in promoting and implementing RI in biomedicine, and which factors have an essential impact on the promotion and implementation of RI in biomedicine in comparison to other disciplines?

4) How to improve RI guidance documents and practices for optimal implementation in biomedicine ang in generally in research?

2.1. Study on RI structures and processes in Europe

This research study, conducted in the form of country report cards, aimed to provide a broad overview of currently existing RI structures and processes in European countries. The study explores and synthesizes the existing RI frameworks in Europe to highlight what structures are important for fostering, promoting, and implementing RI on a national level and

in which countries we can expect more efforts on the organizational level regarding RI promotion and implementation.

2.2. Studies on RI guidance documents and factors influencing the implementation of RI and RI guidance documents

Two scoping reviews were conducted. Scoping review of RI guidance documents in biomedicine and other disciplines and scoping review of factors influencing the promotion and implementation of RI and RI guidance documents in biomedicine and other disciplines. The scoping review of guidance documents aimed to obtain and synthesize information on existing RI guidance documents aimed at RI promotion and implementation in different disciplines. This scoping review aimed to identify the body of literature that will inform on several questions: a) what types of guidance documents currently exist in biomedicine and other disciplines, b) which types of guidance documents exist in research performing organizations and research funding organizations, c) what RI topics are most represented across identified/existing guidance documents, d) what are the most prominent gaps related to the existence and distribution of guidance documents, as well as RI topics addressed in them.

The scoping review on factors aimed to collect the body of literature that contains information on positive and negative factors related to individuals, research organizations, and system of science, that could have an impact on incentivizing or hindering the RI promotion (and RI guidance documents) and implementation in biomedicine and other disciplines. The systemization of knowledge obtained through this scoping review aims to inform how to promote and implement RI more efficiently.

2.3. Study on the development and implementation of RI documents and practices in biomedicine and other disciplinary fields

This qualitative research focused on an in-depth exploration of researchers' and other stakeholders' knowledge and perceptions on the promotion and implementation of RI and RI guidance documents in different disciplines. More specifically, the aim included exploring the processes for developing and implementing RI guidance documents in biomedicine and other disciplines, as well as exploring different factors that may affect the promotion and implementation of RI and RI guidance documents in different disciplines.

3. METHODS

3.1. RI country report cards – overview of research integrity structures and processes in Europe

3.1.1. About research integrity country report cards

The idea for creating RI country report cards first emerged at the 4th WCRI in 2015, where the representatives from various countries discussed the usefulness and feasibility of country report cards in mapping RI structures and processes (134). Country report cards were further discussed during the Mutual Learning Exercises on RI (135) and in the EnTIRE project (136, 137). This study collected information on RI frameworks from 16 European countries and compared them using the template for the country report cards developed in the EnTIRE project.

3.1.2. Study design and data collection

The country report cards contained the following information:

1) research infrastructure, funding, and research strategy (for mapping higher education institutions, research institutions, and the number of full-time researchers; gross expenditures on research and development in public and private sectors; the existence of the national research strategy);

2) research governance, compliance, and integrity structures (national bodies for RI and RE, national RI and RE codes and guidelines for researchers, processes for handling research misconduct cases, and protection of whistleblowers);

3) laws and regulations (existing laws and regulations concerning RI and RE),

4) measures to promote good scientific practices and open science (availability of RI and RE training, communication with the public, and research and RI and RE incentives).

A search of several sources was conducted to obtain relevant information for the country report cards. First, the search of the web pages of the European Network of Research Integrity Offices (ENRIO) and European Network of Research Ethics Committees (EUREC) (138, 139). Further, the internet was searched using the Google search engine and the search terms “research integrity” AND “name of the country”. Finally, web pages of the national research councils and ethics committees, national agencies on RE/RI, national scientific funds, and national academies of sciences for each of the 16 countries were searched. The search was conducted during 2020 and 2021.

3.2. Scoping reviews

The difference between traditional literature reviews and scoping reviews has been explained previously, and it is also important to elaborate on why the scoping review methodology is chosen for this research, instead of the, for example, systematic review. The explanation is closely related to what this research aimed to achieve. While systematic reviews are often used in clinical research to inform practice about, for example, the effectiveness of treatment and provide answers to clinically meaningful questions, scoping reviews have much broader aims. The aim of scoping reviews is not to provide answers to a specific and exact question but rather to map the available evidence or body of literature on a certain topic or research problem and identify gaps in knowledge (130, 140, 141). Defining the existence and availability of certain knowledge and mapping the gaps can further help researchers to pose more specific questions to be explored in, for example, systematic review. Nevertheless, scoping reviews are often used as precursors of systematic reviews. Hence, this study employs the scoping review methodology as the aim is not to provide the answer to one specific question, for example, whether SOPs for RI as guidance documents are used for RI promotion in biomedicine or whether RI education has a positive impact on RI promotion at the level of individual researchers. The scoping reviews in this study aimed to identify the body of literature addressing various RI guidance documents across disciplines and factors influencing the promotion and implementation of RI at different levels of application.

3.2.1. Scoping review on the existing research integrity documents available in biomedicine and other disciplines

Study design

For conducting the scoping review on RI guidance documents, the JBI (previously Joanna Briggs Institute, now JBI) methodology and guidance for conducting scoping reviews were followed (142, 143). The methodology and results of the conducted research are reported following the Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) checklist to ensure the completeness and systematization of research data (144). The PRISMA-ScR guidelines and checklists have several specific terms used in reporting the scoping reviews in this study. In that context, the “information sources” refer to the sources where the publications that contain evidence relevant to the research

questions were searched. This includes bibliographic databases, web pages of research organizations, etc. Furthermore, the "sources of evidence" refer to publications in which data relevant to the research question is found. The publications can be various, such as research articles, commentaries, editorials, or more specific publications of professional societies or research organizations.

Eligibility criteria

This scoping review included analysis of publications from two sources – peer-reviewed journals and grey literature sources. The main eligibility criterion considered for both peer review publications (i.e., research articles, commentaries and editorials when containing enough details or description of guidance documents) and grey literature was that publications address RI guidance documents existing in research performing and research funding organizations. As RI guidance documents can have many forms, this scoping review sets initial criteria for eligibility to guidance in the form of codes, guidelines, checklists, SOPs, flowcharts, legal documents, and policies. This was decided based on the traditional literature search and exploration of the existing formats of guidance documents available through the websites of research organizations or professional societies like ENRIO. However, other types of guidance documents were not excluded from being mapped if discovered during the screening, and the list was updated during the publications' screening and analysis. These other types of guidance documents included reports, statements, declarations, and white papers as these terms were set out in the title or description of the identified guidance document. While the majority of identified guidance documents contained the type of guidance on RI issues in their title or description, for example, for the European Code of Conduct for RI it is evident that the type of guidance document is a code (37), as it is obvious that the COPE (Committee on Publication Ethics) guidelines on good publication practice are guidelines (145). However, some documents did not contain in their title the type of guidance, and for these documents, the criteria were defined to classify these into a specific category of guidance documents. The classification for this research was set as follows:

(a) Code – a document providing general rather than detailed guidance on ethical standards, principles, values, and rules of behavior;

(b) Guideline – a document more specific than code in providing guidance; a document providing specific instructions for performing a certain task or achieving a certain goal;

(c) Checklist – a document presented as a clear list of items to be done, checked, or considered in performing a specific task;

(d) Standard operating procedure – a document providing detailed, step-by-step instructions for carrying out routine tasks aimed at achieving uniformity and efficiency;

(e) Flowchart – a document presenting guidance in the form of a diagram representing a workflow or process;

(f) Legal document – a document established by a government or other authority, empowered by law, and outlining legal consequences; and

(g) Policy – a document established and implemented by an organization, containing adopted principles, rules, and procedures for conducting certain actions.

For peer-reviewed and grey literature publications to be included in the analysis, a description or summary of specific guidance document(s) had to be provided in publications. This means that pure mentioning of certain guidance documents (e.g., the naming of guidance documents) without providing any details on the content and RI guidance document was not enough. To be included in the analysis, the publications had to rather plunge into considering the characteristics and/or RI content of these documents. Moreover, regarding the eligibility criteria, it is important to mention that guidance documents addressing RCR, academic integrity, and RE were also included in the analysis. The reasoning is that, as explained in the Introduction of this thesis, RI and RCR are recognized as synonyms depending on the geographical origin of publications and guidance documents. Further, across much literature, there is still much vagueness when it comes to the distinction between RI, RE, and academic integrity, and often terms are used as synonyms, or the practices behind the terminology are interrelated. To be more specific. Academic integrity, although mostly related to the students and their performance or integrity in fulfilling academic tasks, it often relates to the fundamental values relevant to researchers and their work (146). Hence, this scoping review assumed that some literature referring to guidance documents related to academic integrity would reflect on researchers' performance and professional or unprofessional behavior in the academic setting. These documents were included in the analysis. Now for the RE, the explanation of the complexity of the distinction between RI and RE across existing literature is already provided in the Introduction as well. Starting from the evidence showing that RI and RE are in many research communities still treated as synonyms (32, 147), this scoping review included publications

addressing the RE guidance documents as well since these documents are often related to the questions that are part of what this study considers as RI. For example, the ethical aspects of authorship practices.

A few more things related to the eligibility criteria and search of relevant publications (described in the next section in detail) are important to be mentioned here. First, the study included publications addressing RI guidance documents from biomedical sciences, natural sciences, social sciences, and humanities. These disciplines were already defined in the proposal of the SOPs4RI project as a part of which these studies were conducted. For the publications that were not specifically related to a certain discipline but were more general and referring to general research, the category of "research in general" was created. For example, the European Code of Conduct for Research Integrity is not tied exclusively to a particular discipline (37). It is a guidance document providing more broad or general guidance for RI that can be applied to any discipline or tailored to the disciplinary needs. Second, for the peer-reviewed publications, limitations regarding geographical origin and language of publications were not set, meaning the broad approach was employed to identify as many publications from various countries that could answer the research question. Also, it was taken into account that most scientific publications are written in English; hence a large number of non-English peer-reviewed publications was not expected. Third, for the grey literature search, which was predicted to be obtained in a much larger number in non-English language compared to peer-reviewed publications, the eligibility criteria were set to include only grey literature in English. It was decided so for feasibility, as it would not be feasible and realistic to translate many retrieved documents to be analyzed. Finally, as outlined in the introduction of this study, RI as a field gained much popularity since the early 1990s when cases of research misconduct became more prominent, and the need for regulations and policies became more apparent. Accordingly, the scoping review aimed to include only publications (both peer-reviewed and grey literature) dating from the 1990s onward to ensure the applicability and contemporaneity of identified guidance documents in publications, as well as currently existing gaps in knowledge.

Information sources and search

To identify relevant publications, the identification of information sources for peer-reviewed and grey literature was made, together with the development of the search strategy. For the peer-reviewed publications, the information sources were the following bibliographic

databases: Medline, Scopus, Web of Science (WoS, Core Collection), and PsycINFO. The search of Medline, WoS Core Collection, and Scopus was performed on 18 February 2019, while the search of PsycINFO was performed on 12 February 2019. The obtained data were exported to the EndNote™ tool (Clarivate Analytics, Philadelphia, PA, USA) for screening and further analysis. Search strategies for bibliographic databases are developed with the help of the librarian specialized in systematic review search methodology. As a starting point for developing the search strategy, the concepts and terms from the European Code of Conduct for Research Integrity were used (37). After developing the outline and the first version of the search strategy, following the requirements and scoping review research questions, the search strategy was modified and improved with the librarian's help. The finalized search strategy for bibliographic databases that was used for obtaining the publications included in this scoping review is presented in **Appendix 1**. It is important to mention that the search strategy development aimed at high sensitivity rather than precision and included a broad approach to the RI field. Although the literature states that the ideal search strategy would aim for high sensitivity and precision (which are however inversely related) (148) the rationale for ruling in favor of a highly sensitive but less precise search strategy is closely related to the mere usage of the scoping review methodology – identification and mapping as much as possible publications that could be relevant for research question and aim. Hence, the search strategy for this scoping review aimed at high sensitivity to identify as many relevant documents as possible that will provide a realistic overview of the publications on existing RI guidance documents.

Information sources for the grey literature were: Open Grey database (149), World Conferences on Research Integrity (WCRI) (52) website, the Community Research and Development Information Service (CORDIS) database (150), Office of Research Integrity (ORI) website (151), European Network of Research Integrity Offices (ENRIO) website (138), the National Academies of Sciences, Engineering, and Medicine (NASEM) publications (152), Science Europe publications (153), Mutual Learning Exercises (MLE) on Research Integrity reports (135), and the League of European Research Universities (LERU) publication (154). Search strategies and details of the search of grey literature sources are available in **Appendix 2**.

Selection of sources of evidence

This section outlines the process of selecting the sources of evidence, i.e., publications screened and included in the analysis. To start with selecting the sources of evidence from the bibliographic databases. After the search of the bibliographic databases was conducted, the further systematized steps included the removal of the duplicate publications, followed by the initial screening of titles and abstracts. As the JBI methodology for conducting scoping reviews was employed, two independent researchers screened the titles and abstract to ensure the robustness of the process and results. Moreover, to precisely define the criteria for inclusion and exclusion of the publications and ensure that both independent reviewers correctly understand the set criteria and perform the task in the same manner, a pilot screening of the titles and abstracts of 100 records was performed. The pilot screening results were compared and discussed between researchers, and no additional changes were introduced to the initial criteria, which meant that everything was ready for screening all obtained publications. After the initial titles/abstracts stage was completed, the obtained results were discussed between reviewers, and in cases of disagreements on whether to include or exclude a certain publication, a third researcher was included in the decision-making process. The following step included a full-text assessment of the publications that three reviewers performed. The ultimate goal of this step was to identify publications eligible for inclusion in the final analysis and data extraction. To be included in the final analysis, a consensus between at least two researchers had to be reached. In cases of major disagreements, another reviewer was included in the decision-making process to reach the final decision. Since some peer-reviewed publications were not in English, the material was translated using tools such as Google translate to explore the fulfillment of the eligibility criteria. Moreover, after reaching a consensus on the set of publications to be included in the final analysis, reference lists of these publications were screened to identify additional publications that were not obtained through the initial search.

For grey literature sources, the search for the relevant sources of evidence included one researcher performing the search to identify documents that specifically fulfill the set eligibility criteria. All available documents were not extracted; rather, the full-text screening was performed simultaneously with the search to achieve optimization and the feasibility of the process. The PRISMA flow diagram presented in the Results section outlines the steps of the

screening process as well as the number of publications screened and subsequently included in the final analysis.

Data charting and data synthesis

A set of items for the data extraction from the publications was defined following the a priori reasoning on the data required for providing answers to research questions and demonstrating the main characteristic of the body of literature included in the synthesis. However, the list of items was considered to be a living document, aimed to be continually updated throughout the screening of the publications as new relevant items could be identified during the screening process. The final list was achieved through a discussion between two researchers who performed the data extraction. The final data extraction list included the following items: author(s) (for publications from bibliographic databases); title (for publications from bibliographic databases); year of publication; reference type, i.e. journal article, book, book section (for publication from bibliographic databases); journal (for publications from bibliographic databases); country of origin; research fields, i.e. humanities, social sciences, natural sciences (including engineering), biomedical sciences, research in general; title of the guidance document(s) mentioned; type of guidance document, i.e. code, guideline, checklist, SOP, legal document, report, declaration, statement, flowchart, white paper, policy; whether the guidance document(s) was more related to research performing organizations or research funding organizations, or both; whether the guidance document was more related to organizations or individuals or equally to both; target audience in guidance document(s), i.e. researchers, research groups, policymakers, funders, students, mentors and supervisors, committees and members of committees, RI offices and officers, RI advisors, ombudsman, reviewers, administrators, whistle-blowers; description of the information source (for grey literature); principles addressed in guidance document(s).

Identified RI guidance documents were further categorized according to the regular phases of the research process – planning, conducting, dissemination, and evaluation – as well as RI violations and resolutions and RI promotion, which are important aspects of the RI field as well. Within each research process, more specific RI topics were identified to capture the most relevant concepts and issues addressed across guidance documents. The aim of including topics and categorizing documents into topics aimed at creating a systemized overview and map of existing knowledge and gaps in knowledge. Furthermore, the RI principles, often mentioned

across guidance documents and used as aspirational guidance for creating more specific RI guidance, were extracted. This was done only for the RI guidance documents that explicitly mentioned and explained RI principles. The extracted principles were mapped to the principles presented in the European Code of Conduct for Research Integrity (37) and those presented in the United States National Academies of Sciences, Engineering, and Medicine in the book Fostering Integrity in Research (3). The two guidance documents were chosen since both present the RI framework widely implemented across European and US research structures. This analysis aimed to observe the similarity in principles and terms used to address the guiding principles.

Following the data extraction process, all publications were summarized based on their geographical origin, discipline, the organizational origin of the identified guidance document(s) (research performing or funding organization), type of guidance document(s), target group to which the guidance was directed, as well as RI topics addressed in guidance documents.

3.2.2. Scoping review on the individual, organizational, and systemic factors influencing the implementation of research integrity in biomedicine and other disciplines

Study design

Similarly to the previously explained reasoning for the first scoping review, to explore as many as possible factors influencing the promotion and implementation of RI, to map the body of literature relevant to the research questions, and to identify gaps in knowledge, a second scoping review was conducted. Moreover, this scoping review, the same as the one on the RI guidance documents, follows the JBI guidelines for conducting scoping reviews, and its methodology is described below following the PRISMA-ScR reporting guidelines (144).

Eligibility criteria

This scoping review included peer-reviewed and grey literature publications related to the factors that may positively or negatively impact the promotion and implementation of RI among individual researchers, organizations, and the system of science in different disciplines – biomedicine, natural science, social sciences, and humanities. For the publications not related to the factors in any specific discipline but concerning factors influencing RI implementation in general, a category “research in general” was also created. For the peer-reviewed publications, no limitations were set regarding the type of publication, i.e., empirical research articles,

editorials, and commentaries were all set to be included in the scoping review. However, for the commentaries and editorials, the possibility of being included in the analysis was open if they contained enough information about factors influencing the promotion and implementation of RI (e.g., details about the effect of certain factors rather than just listing or referring to different factors without any details or appropriate explanations). For the empirical studies, no limitations were set regarding the study design. Moreover, for the peer-reviewed publications to be included in the scoping review a limitation was not set regarding the language or geographical origin. For the grey literature search, the same as for the first scoping review, this scoping review aimed to include only English language publications. The limitation regarding the year of publication for both peer-reviewed and grey literature publications was set to the year 1990, as it was expected, taking into account the development of the RI field, that older publication would not offer an insight into the current state of affair regarding the factors influencing RI environment, especially if we take into account the globalization of research and constantly progressing research endeavors. Same as the first scoping review, this scoping review did not exclude publications related to academic integrity and research ethics, which are close and often across publications used as synonyms for RI if these publications referred to the research questions.

Information sources and search

This scoping review included peer-reviewed publications from the bibliographic databases Medline, Scopus, WoS Core Collection, and PsycINFO. The search strategy for this scoping review was the same strategy used in the scoping review on RI guidance documents. As explained in the previous sections, the search strategy used in the scoping reviews was developed to be high in sensitivity to retrieve as many documents from the RI field related to the research questions and aim. This means that the search strategy was not aiming at high precision, and during the development, already in the planning phase, it was intended and designed to capture concepts and search terms that would suit the needs of both scoping reviews. Another reason for this is that the scoping reviews were a part of the larger project, and for the project's feasibility, the search strategy was used for both scoping reviews. However, after obtaining the body of literature with the initial search, the eligibility criteria employed for further screening and synthesis were specific and differed between scoping reviews, meaning that the final publications were not the same as for each scoping review, the screening process and analysis were done separately. The information sources for grey literature were the WCRI web

pages, the CORDIS database, and the National Academies of Sciences, Engineering, and Medicine publications. The search strategy for bibliographic databases is available in **Appendix 1**, and details of the search of grey literature sources are available in **Appendix 2**.

Selection of sources of evidence

After performing the search and obtaining the initial body of peer-reviewed literature, publications, i.e., sources of evidence, were extracted to the EndNoteTM tool (Clarivate Analytics, Philadelphia, PA, USA), followed by removing duplicate publications and performing the pilot screening to check the eligibility criteria and selection process between researchers. The first 100 publications were pilot screened by three researchers, and obtained results were discussed. As there were no major disagreements and the set criteria were clear, three researchers screened titles and abstracts to eliminate publications not relevant to the research questions and aim. In the next step, two researchers independently performed full-text screening and discussed the results with the third researcher to reach a final decision. After obtaining the final list of peer review literature to be included in the analysis and synthesis of evidence, the reference lists of these publications were screened for the possibility of identifying additional publications that were not captured or were omitted in the search and screening process. One researcher screened the information sources of grey literature following the eligibility criteria in identifying relevant studies.

Data charting and data synthesis

A data charting form was developed in advance (and updated during the extraction process), and one researcher extracted data after the full-text screening. Data charting form included the following items: author(s); title; year of publication; reference type (for publications from bibliographic databases; e. g. journal article, book); country of origin; disciplinary field; relation to research performing organizations, research funding organizations, or both; identified factors (related to the individual researchers, organization, or the system of science); impact of factors (positive or negative). The empirical studies testing RI interventions also included a short description of the intervention.

After data extraction, publications, and extracted items were grouped by several criteria. First, the publications were grouped by general characteristics, such as year of publication, type of publication, country of origin, disciplinary field, relatedness to the research performing

organizations, research funding organizations, or both. Further, publications were mapped based on the distinction between different levels and factors influencing RI promotion and implementation; more precisely, this included mapping based on the relatedness of factors to individual researchers, organizations, and system of science. Further, identified factors in the publications were categorized based on their positive or negative impact on RI promotion and implementation, followed by grouping factors into topics to create an overview of RI-related areas addressed in publications. Finally, the following items were extracted for studies describing interventions: study design, intervention approach, sample size, outcome measure, and reported limitations.

Critical appraisal of sources of evidence

The purpose of the critical appraisal of evidence is to assess the methodological quality of the studies and analyze whether appropriate steps were taken to reduce the risk of bias (155). Although critical appraisal of evidence is more characteristic of the systematic review than scoping review since the latter aims to provide just an overview of the existing evidence related to the research question and aim, this scoping review assesses the methodological quality and risk of bias was performed. This was decided based on the guidance on conducting scoping reviews that says that critical appraisal of evidence can be conducted if that is expected due to the nature of the scoping review (132, 142). Since the aim of this scoping review was to examine factors that have a positive or negative impact on RI promotion and implementation, and it was expected that some of these factors will be related to certain RI interventions, such as RI education, the decision to perform the critical appraisal of evidence was brought to have a complete overview not only on factors and interventions but also on their effectiveness in real life setting. For assessing the methodological quality of studies describing the interventions, JBI Critical Appraisal Tools were used. This included the JBI critical appraisal checklists for quasi-experimental (non-randomized experimental studies), randomized controlled trials, and qualitative studies (155,156). The checklists contain questions to assess the methodological soundness, and four items (Yes; No; Unclear; Not applicable) are used as answers. The critical appraisal of evidence was conducted independently by two researchers to ensure the robustness of the process.

3.3. Qualitative study on the development and implementation of research integrity documents and practices in biomedicine and other disciplinary fields

In reporting the methodology and results of the qualitative study in the following text, the Consolidated Criteria for Reporting Qualitative Research (COREQ) checklist is used (157).

3.3.1. Study design and outcome measures

As mentioned previously, since the aim of the qualitative study was to explore in-depth and obtain knowledge of various stakeholders on RI promotion and implementation, as well as on RI guidance documents and factors related to their development and implementation, semi-structured interviews were used as the appropriate methodological approach. Semi-structured interviews are suited for obtaining opinions and thoughts from individuals in certain groups and enable new ideas to be discussed during the session, in addition to predefined interview questions and a developed interview guide (133).

The interview guide was based on the main findings from the scoping reviews that informed on existing evidence and gaps ready to be further explored in more in-depth discussions. The first version of the interview guide was developed by one researcher and discussed with two other researchers to ensure the proposed questions were adequately created and formed in relation to the study's aim. The pilot interview was conducted to test the interview questions, which were then refined through the discussions among researchers. In this second version of the interview guide, the focus was put on the SOPs as a type of RI guidance document, as well as on barriers and facilitators of successful implementation of RI and RI guidance documents. The reason for focusing more on the SOPs in the second version of the interview guide was based on the findings from the scoping review that showed only a small number of SOPs for RI. This indicated that this type of guidance document, although pretty regular and useful in some areas (e.g., industry, clinical practice, or laboratory research), is still not well known in the RI field but was recognized in the pilot study by researchers as useful guidance.

3.3.2. Participants

The purposive sampling technique was used to recruit participants from different groups of stakeholders. In this study, 23 interviews were conducted with participants with experience in the RI field. The recruiting process explicitly aimed at recruiting stakeholders who had experience working in the RI field, as participants needed knowledge of different RI guidance

documents as well as their development and implementation. Moreover, participants needed to be familiar with the prominent challenges of RI promotion and implementation. The following groups of stakeholders were included: researchers/educators (n=16), policymakers (n=5), members of RI/RE committees (n=5), members of industry (n=6), and members of funding organizations (n=1). The numbers do not add up to the total number of participants because participants could select multiple stakeholder groups in the demographic questionnaire.

The sample consisted of 13 female and 10 male participants. In the recruiting process, the emphasis was placed on having a gender balance in the sample. The median years of work experience related to RI were 10 years (range 2–32). Most participants were from European countries (1 each from Austria, France, Germany, Luxembourg, Norway, Poland, and Portugal, 2 from Belgium and Croatia, 3 from Italy and the United Kingdom, 4 from the Netherlands); one from the USA, and one from Australia. Regarding disciplines, most participants were from biomedical sciences (n=9), followed by social sciences (n=7), humanities (n=5), and natural sciences (n=2). Participants were primarily identified through personal contacts and approached via e-mail or in person. There were 3 dropouts from the study – 2 participants did not feel comfortable participating because of the lack of RI-related experience (self-assessment), and 1 participant had other commitments.

3.3.3. Setting and data collection

The interviews were conducted from March to July 2019, face-to-face (n = 14) or online (n=9), depending on the participants' availability. The interview guide used during the interviews is available in **Appendix 3**, and the demographic questionnaire used for obtaining demographic data is available in **Appendix 4**. The invitation letter and informed consent used in the interviews are presented in **Appendix 5**. Only the facilitator and the interviewee were present during the interviews, except for the pilot interview, in which two facilitators were present. This was done to assess better the need for possible changes in the first version of the interview guide. Non-participants were not present during the interview to ensure adherence to the principles of privacy and confidentiality.

Based on the predefined workload set out in the study protocol, interviews were facilitated by two researchers from the University of Split School of Medicine and six collaborators in the SOPs4RI project. Most participants were familiar with the research team, as the RI research field is rather small. During the recruitment process, the participants were

informed about the aims and the process of the research, as well as other relevant information through the invitation and information letter. More information on the ethical considerations and informed consent procedure are available in the section Ethical questions.

The analysis of the interviews was performed by two researchers with experience in qualitative analysis. Interviews were from 30 minutes to 1 hour and 15 minutes long, conducted mostly in English, and audio recorded. One interview was conducted in Polish and two in Italian since these participants felt more comfortable speaking their native language. These interviews were translated into English after the transcription process. Audio recordings were transcribed verbatim and prepared for analysis in the NVivo 12 Plus software for Windows (QSR International, London, UK). Field notes were made by the facilitators during some interviews, mostly as a note to themselves to mark additional questions that were not defined in the interview guide but rather emerged from the discussion. Field notes were not mandatory to be taken and were not included in the analysis. The transcripts were not returned to the participants for comments and corrections. Repeated interviews were not carried out.

3.3.4. Data analysis

In the analysis, the reflexive thematic analysis approach by Braun and Clarke was followed (158, 159). This approach enabled flexibility in the quest for knowledge and a detailed understanding of the explored issues. The first step in the analysis was familiarization with the data through the transcripts. The second step included active coding and pursuit for generating the initial codes to develop broader themes and concepts. The development of codes included the inductive coding approach and semantic codes were used. This captured the explicit meaning of the data and the focus was not on the potential deeper or conceptual meaning of each code. Rather, as mentioned above, codes were used as a first step in discovering and defining more broader themes and concepts that provide a deeper understanding of the explored issues. After finalizing the list of codes, the next step in the process included the construction of themes, followed by revision and modification of the themes until the final list was developed. In the reflexive thematic analysis approach, the concept of data saturation is not applicable (160); hence data saturation was not sought to be obtained.

3.3.5. Ethical questions

The ethics approval for conducting the interviews was obtained by the Ethics Committee at the University of Split School of Medicine (Document No. 2181-198-03-04-19-0011). All ethical and legal questions and requirements were strictly followed in recruiting participants and conducting interviews. All participants were, upon invitation, provided with the information letter describing the study's aim and their involvement in the research, with potential risks and benefits and relevant contact information. The informed consent procedure involved participants asking questions regarding their participation to bring informed and voluntary decisions about participation. To participate in the study, the participants had to sign the informed consent form and send it back to the researchers before the commencement of the interview or hand it in at the time of the interview. Voice recordings from the interviews were used only for obtaining the transcripts, and the transcripts were pseudonymized. Data obtained from the demographic questionnaires were also pseudonymized.

4. RESULTS

4.1. RI country report cards – overview of research integrity structures and processes in Europe

4.1.1. Research infrastructure, funding, and strategy

The first category included in the country report cards focused on the research infrastructure, funding, and research strategy and aimed to map the general research frameworks or research environment existing across 16 European countries. This data provided input into how much each country invests in research by the number of full-time researchers, the number of universities, the gross expenditures on research and development as a part of the countries' gross domestic product, and whether each country has an implemented research strategy. The analysis showed considerable differences between countries. Northern and some western European countries have more full-time researchers than eastern and southern European countries. For example, Scandinavian countries, with Finland leading, have the highest number of full-time employed researchers per million inhabitants. The lowest number of full-time researchers was identified in Moldova. Regarding the number of universities, the country with the highest number of universities is Spain (n=75), followed by Austria (n=55) and Bulgaria (n=51). The country with the lowest number of universities is Luxembourg with a single university. But of course in interpreting these results we must take into account the country size, as larger countries will have more universities. The data concerning gross expenditures on research and development were used for the research funding data. Sweden has the highest research and development investment in research and development, which comprises 3.4% of the country's gross domestic product. Countries whose research and development gross expenditures are below 1.0% of their gross domestic product are Croatia (1.0%), Bulgaria (0.8%), and Moldova (0.3%). The analysis showed that all 16 countries have research strategies developed and implemented nationally. Details of the analysis are presented in **Table 1.**

Table 1. Research infrastructure, research funding, and research strategy in analyzed countries

Country	Research infrastructure		Research funding		Research strategy
	The number of full-time researchers (year) / the number of full-time researchers per million inhabitants	The number of universities	Gross expenditures on R&D (year)	Part of the GDP	
Austria	52,554 (2019) / 5,868	55	€11.518 billion (2017)	3.11%	Strategy for Research, Technology and Innovation for the next decade (2011)
Bulgaria	16,940 (2019) / 2,419	51	€389 million (2017)	0.75%	National strategy for development of scientific research in the Republic of Bulgaria 2017-2030 (Better Science for better Bulgaria)
Croatia	11,801 (2016) / 2,804	12	€76,231,740 (2018)	0.97%	The Strategy for Education, Science and Technology of the Parliament of the Republic of Croatia (2014)
Denmark	42,378 (2019) / 7,342	8	€8.921 million (2017)	2.93%	Denmark – Ready for the Future (2018)
Estonia	4,968 (2018) / 3,755	7	€452,97 million (2019)	1.61%	The Estonian Research and Development and Innovation Strategy 2014-2020 "Knowledge-based Estonia"
Finland	51,500 (2019) / 9,309	14	€6.7 billion (2019)	2.79%	The Finland's Strategy and Roadmap for Research Infrastructures 2014-2020.
France	431,000 (2016) / 6,664	116*	€51.8 billion (2018)	2.20%	The research strategy France Europe 2020 A Strategic Agenda for Research, Technology Transfer and Innovation
Greece	40,084 (2019) / 3,827	24	€2,336.58 million (2019)	1.27%	National Research and Innovation Strategy for Smart Specialization 2014-2020.
Ireland	37,310 (2019) / 7,641	8	€4.027 million (2019)	1.13 %	The five-year strategy on research and development, science and technology, entitled Innovation 2020.
Lithuania	9,538 (2019) / 3,456	18	€483.868 million (2019)	0.99%	The Lithuania's Progress Strategy "Lithuania 2030"
Luxembourg	3,158 (2019) / 5,128	1	€704.5 million (2018)	1.17%	The "National Research and Innovation Strategy"
Moldova	2,466 (2018) / 608	22	€34,4 million (2018)	0.25%	The National Development Strategy "Moldova 2030" (2018)
Norway	46,600 (2018) / 8,729	10	€7.13 billion (2018)	2.06%	The first long-term plan for research and higher education in 2014
Spain	135,331 (2019) / 2,895	75	€15.572 million (2019)	1.25%	The Spanish Strategy on Science, Technology and Innovation 2013-2020 (2013)
Sweden	91,172 (2019) / 9,084	17	€16.8 billion (2019)	3.41 %	Life sciences road map – pathway to a national strategy
The Netherlands	97,713 (2019) / 5,715	18	€16.554 million (2018)	2.14%	2025 – Vision for Science choices for the future

4.1.2. Research governance, compliance, and integrity structures

For the analysis of governance, compliance, and integrity structures, the data concerning the national bodies for RI and RE, national RI guidance documents and guidelines for researchers, practices for handling research misconduct, and the protection of whistleblowers were taken into account (**Figure 1**). Collected details for this category of data are presented in **Table 2**.

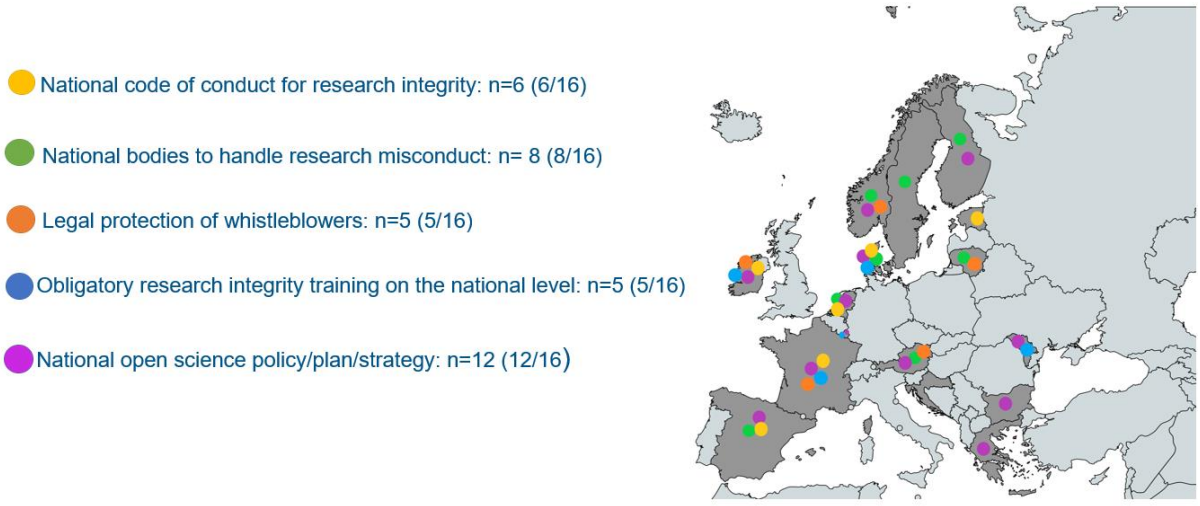

Figure 1. Overview of research governance, compliance, and integrity structures.
N represents the number of countries.

Table 2. Research governance, compliance, and integrity structures in analyzed countries

Country	Research governance, compliance, and integrity structures			
	The number of national bodies promoting RE/RI	**Bodies that handle research misconduct**	**National Code of conduct for RI**	**Legal protection of whistleblowers**
Austria	5	Austrian Agency for Research Integrity	No	Yes
Bulgaria	3	Academic Ethics Committee	No	No
Croatia	1	Ethics committees in research institutions	No	No information
Denmark	6	The Danish Committee on Research Misconduct	Yes (The Danish Code of Conduct)	No
Estonia	4	Ethics committees in research institutions	Yes (The Estonian Code of Conduct for Research Integrity)	No
Finland	6	Finnish National Board on Research Integrity (TENK)	No	No information
France	8	Research institutions	Yes (National charter for research integrity)	Yes
Greece	3	Ad-hoc committees or research institutions performing organizations	No	No
Ireland	2	Research institutions perform investigations	Yes (Policy Statement on Ensuring Research Integrity in Ireland)	Yes
Lithuania	4	Office of the Ombudsperson for Academic Ethics	No	Yes
Luxembourg	4	Luxembourg Agency for Research Integrity (LARI)	No	No
Moldova	No official structure	Ethics committees at research institutions	No	No
The Netherlands	6	Boards at research institutions (advised by the Netherlands Board on Research Integrity /LOWI/)	Yes (Netherlands Code of Conduct for Research Integrity)	
Norway	6	The National Commission for the Investigation of Research Misconduct (GRU)	No	Yes
Spain	5	Ethics Committee of the Spanish National Research Council (CSIC)	Yes (Code of Good Scientific Practices of CSIC and the Spanish National Statement of Research Integrity.	No

Sweden	4	The National Board for Assessment of Research Misconduct	No	No information

CSIC – Spanish National Research Council; GRU – National Commission for the Investigation of Research Misconduct (Norway); LARI – Luxembourg Agency for Research Integrity; LOWI – Netherlands Board on Research Integrity; TENK – Finnish Advisory Board on Research Integrity

National bodies for RI and RE

The analysis showed that most of the countries included in this study have established policies, structures, and processes for RI and RE, but these differ in certain aspects. Regarding RI and RE bodies, almost all countries included in the analysis have official national structures responsible for providing RI and/or RE governance framework. However, only 8 countries have bodies responsible for officially handling research misconduct cases. Otherwise, these cases are handled at the institutional level or in cases of research frauds in the courts of justice. France, for example, has eight national bodies that promote RI together with RE. These bodies have advisory and monitoring roles and support research institutions and universities. The Austrian agency for research integrity handles research misconduct cases and provides RI education and advises on RI issues for public research organizations. In Croatia, there is no official national RI body, but the National Ethics Committee is established for providing advice and resolutions in cases of RE breaches and RI standards. Moldova is the only country without an official RI and RE structure. The Moldovan National Authority for Integrity deals only with public servants and heads of institutes. It does not address RI or researchers in general.

National codes for RI and guidelines for researchers

The analysis showed that six countries (Denmark, Estonia, France, Ireland, Spain, and the Netherlands) have national codes for RI. And although, for example, Finland, Norway, and Sweden do not have national codes for RI, organizations and national societies responsible for promoting RI in these countries have developed various guidelines for researchers and other stakeholders involved in the research process. Among these countries, Finland has the highest number of guidelines. These include “Responsible conduct of research and procedures for handling allegations of misconduct in Finland”, guidelines of the Finnish Advisory Board on Research Integrity 2012” and “Responsible Conduct of Research (RCR) guidelines” available

in Finnish, Swedish, and English (161, 162). Norway has several national bodies for promoting both RI and RE. These bodies have issued several guidelines and checklists regarding ethics and integrity in research across different disciplines. The National Commission for Research Ethics in Science and Technology (NENT) developed Guidelines for Research Ethics in Science and Technology (163), the National Committee for Research Ethics in Social Sciences and Humanities (NESH) issued Guidelines for Research Ethics in the Social Sciences and Humanities (164), whereas the National Committee for Medical and Health Research Ethics (NEM) published various guidelines. Sweden also does not have a national code for RI , but the Swedish Research Council developed ethical guidelines and there is also an internal Expert Group on Ethics which has published the book Good Research Practice (165), intended primarily for researchers.

Processes for handling research misconduct

European countries included in this analysis differ when it comes to bodies that handle allegations of research misconduct. Some countries have specific national bodies that handle cases of research misconduct, while in others research institutions, such as universities, are responsible for dealing with such cases. However, some of these research institutions are affiliated with independent bodies that advise possible violations of the RI. For example, institutional boards in the Netherlands that handle research misconduct cases are often advised by the Netherlands Board on research Integrity (LOWI). Greece, apart from having research institutions dealing with allegations of research misconduct and specific cases related to these allegations, sometimes has ad-hoc committees for handling research misconduct cases. Croatia, as previously mentioned, has a national body for RE and RI, but it does not seem to be functional at this moment, at least in the area of dealing with misconduct cases.

Legal protection of whistleblowers

The country report cards analysis showed that countries also differ when it comes to the legal protection of whistleblowers in research. Some countries (Austria, France, Ireland, Lithuania, Norway, and the Netherlands have specific legal acts for the protection of whistleblowers in research. For example, in the Netherlands, scientific integrity counselors are appointed at universities for assisting both whistleblowers and those suspected of research misconduct. Bulgaria, Denmark, Estonia, Greece, Luxembourg, Moldova, and Spain do not

provide legal protection for whistleblowers. And resources that we searched for relevant information did not provide data for Croatia, Finland, and Sweden in this matter.

4.1.3. Laws and regulations

In this analysis, the existing laws and regulations concerning RI and RE were mapped, and significant differences between analyzed countries were found, i.e., the number of laws and regulations differed between countries (**Table 3**). For example, the Netherlands has 17 laws and regulations concerning RI and RE, while Croatia has 2. Norway, for instance, has a Research Ethics Act and Research Ethics Regulation for regulating ethics in research and examining research misconduct. Denmark has the Research Misconduct Act and Executive order of the Danish Committees on Scientific Dishonesty, while Sweden has an Act on responsibility for good research practice and the examination of research misconduct. Austria, Estonia, Finland, France, Luxembourg, Norway, Spain, and the Netherlands have national laws for protecting animals in research. All countries have some laws on establishing and regulating work of universities or higher education institutions in general. Data protection in research is well-regulated and established by national laws. This is mostly due to the General Data Protection Regulation (GDPR), which provisions are mandatory in almost all countries included in the analysis since these countries are EU member states. However, the GDPR explicitly provides freedom and obligations to member states to further regulate the data protection issues via national laws, including data protection in research. Not all countries included in the analysis have such national laws or at least adequately developed ones (Croatia is an example).

Table 3. Laws and regulations concerning RI and RE

Country	Laws and regulations				
	The number of laws	**Laws that regulate ethics in research and examine misconduct**	**Protection of animals in research**	**Regulation of higher education institutions**	**Personal data protection**
Austria	6	No	Yes	Yes	Yes
Bulgaria	15	No	No	Yes	
Croatia	2	No	No	Yes	
Denmark	6	Yes (Research Misconduct Act and Executive order of the Danish Committees on Scientific Dishonesty)	No	Yes	
Estonia	7	No	Yes	Yes	
Finland	8	No	Yes	Yes	Yes
France	5	No	Yes	Yes	
Greece	5	No	No	Yes	Yes
Ireland	9	No	No	Yes	Yes
Lithuania	10	No	No	Yes	
Luxembourg	6	No	Yes	Yes	Yes
Moldova	6	No	No	Yes	
Norway	11	Yes (Research Ethics Act and Research Ethics Regulation)	Yes	Yes	
Spain	10	No	Yes	Yes	Yes
Sweden	7	Yes (Act on responsibility for good research practice and the examination of research misconduct)	No	Yes	Yes
The Netherlands	17	No	Yes	Yes	Yes

4.1.4. Measures to promote good scientific practices and open science

This category of analysis in country report cards contained three sub-themes – RI training, RI dialogue and communication, and RI incentives. These subcategories captured information related to the availability and types of RI training and educational initiatives, open science initiatives, and communication initiatives (information related to informing society about RI and research misconduct cases and organizations participating in the international RI networks), and incentives for research (evaluations and awards for organizations and individuals based on research output, as well as incentives for collaborative science).

RI and RE training and education

This analysis explored whether there are national efforts for RI training across countries, as well as the main characteristics of RI training and education (the obligatory or non-obligatory nature, model of delivery, and targeted audience). The collected data showed great diversity between countries regarding the compulsory and voluntary nature of RI training. Interestingly, this diversity is not only seen when comparing countries, but within a single country, there are often differences regarding the obligatory and non-obligatory nature of RI training that is provided across research organizations. For example, in Austria, RI training is mostly non-mandatory, but some doctoral programs and some universities made it mandatory for those who want to qualify for academic positions (professorship). In some countries that were included in the analysis, RI training is mandated on the national level. For example, a government body has brought a decision or policy making RI training mandatory for those performing research in public research organizations. This is the case with Denmark, France, Ireland, Luxembourg, and Moldova. In these countries, RI training is mandatory for at least doctoral students and postdoctoral researchers in publicly-funded research organizations. Who delivers the RI training also differs between countries. Austria, Ireland, and Luxembourg have national RI agencies for RI training (Austrian Agency for Research Integrity, Luxembourg Agency for Research Integrity, and Irish National Research Integrity Forum). Research organizations usually provide training in Denmark, France, Moldova, and the Netherlands. Analysis of data from Bulgaria, Croatia, Estonia, Finland, Greece, Lithuania, Norway, and Sweden showed that RI training exists on the organizational level but it is questionable whether the training is obligatory or it is up to researchers to decide whether to undergo the training or not. Regarding the type or mode

of delivery of RI training, it also varies across European countries and research organizations. RI training is provided in many forms, such as face-to-face lectures, workshops, and seminars. Some put more emphasis on practical, interactive, and creative courses, rather than on theoretical lectures. The overview of RI training and its characteristics across countries is presented in **Table 4**.

Table 4. Characteristics of RI training across different European countries

Country	Obligatory/non-obligatory	Type and delivery mode	Targeted population
Austria	Non-obligatory except for programs funded by Austrian Science Fund, some PhD programs, at some universities for those who want to qualify as professors	Workshops, lectures, and train-the-trainer courses delivered by Austrian Agency for Research Integrity	PhD students, researchers, RI officers and ombudsmans
Bulgaria	Non-obligatory/unknown (RE training is obligatory for members of ethics committees and Multi-Centre Ethics Committee; some training is provided by Committee on Academic Ethics and Bulgarian Drug Agency)	Seminars and training sessions	Members of RE committees, researchers
Croatia	Non-obligatory (some elements of RI and RE are part of higher education programs and there are initiatives to introduce RI and RE via elective undergraduate courses as well as to train researchers in the form of summer school programs)	Lectures, workshops, and train-the-trainer courses	Undergraduate students, PhD students, researchers
Denmark	Obligatory (mandated by the Ministry of Higher Education and Science)	Lectures, workshops provided by research organizations	PhD students, postdoctoral researchers, researchers
Estonia	Non-obligatory (depend on research organization; all universities offer introductory courses in RE; Estonian Research Council provides some educational activities)	Lectures, workshops, seminars	Undergraduate students (RE), PhD students (RE), researchers
Finland	Non-obligatory (depends on research organization; some training for RE/RI advisers is provided by Finnish National Board on Research Integrity; some universities offer RE/RI training for PhD students and teachers)	Lectures, online courses	RE/RI advisors, teachers, PhD students
France	Obligatory (mandated by Ministry of Higher Education, Research and Innovation)	Lectures, workshops, seminars provided by research organizations; the MOOC "Research Integrity in Research Professions" lectures, workshops, discussions; educational courses provided by French Office for RI (for RI officers)	PhD students, researchers, RI officers
Greece	Non-obligatory (depends on research organizations; some elements of RI are part of higher education program – Responsible Conduct of Research-Greece educates master's students at two universities; some education is provided by the	Lectures, seminars, training courses, train-the-trainer courses	Undergraduate students, PhD students, researchers, educators

	Hellenic National Bioethics and Technoethics Commission, the Laboratory for the Research of Medical Law and Ethics, and Ethical Aspects in Research and Technology for Human Network; education is also provided at National technical University of Athens)		
Country	**Obligatory/non-obligatory**	**Type and delivery mode**	**Targeted population**
Ireland	Obligatory for publicly funded researchers (the National Forum on Research Integrity has put training in place and research organizations have the autonomy to decide at which level the training will be implemented)	Online training course	Researchers and other academic staff, PhD students
Lithuania	Non-obligatory (some universities provide training, for example Vilnius University offers General Competence Skill Training related to publication ethics; some training is provided by the Office of the Ombudspersons for Academic Ethics and Procedures)	Training courses	PhD students, researchers, librarians, members of academic integrity committees
Luxembourg	Obligatory for PhD students	Educational, interactive, and creative sessions and workshops (delivered by Luxembourg Agency for Research Integrity); peer coaching programs (Luxembourg Agency for Research Integrity); training courses (University of Luxembourg); training and workshops (Luxembourg Institute of Health)	PhD students, researchers, RI coaches
Moldova	Obligatory for undergraduate and doctoral students (mandated by Ministry of Education, Culture, and Research)	Lectures, seminars	Undergraduate students, PhD students
Norway	Non-obligatory (RE training is made obligatory at research organizations by the Research Ethics Act)	Lectures, meetings	Researchers
Spain	Non-obligatory (some universities and research organizations have integrated a module about RI in their existing program on RE – Autonomous University of Madrid, University of Barcelona, University of Oviedo and National University of Distance Education; some members of CSIC Ethics Committee give lectures on RI and RCR; RI and RE training have been included as topics in CSIC management and Training Course for CSIC directors and managers)	Lectures	Students, directors and managers
Sweden	Non-obligatory (depends on research organizations; some education is also provided by Ethics Council, Swedish National Data Service, and National Quality Registers at the Swedish Association of Local Authorities and Regions, Regional Register Centers and related stakeholders)	Lectures, seminars, workshops, conferences, discussion forums, training events	PhD students, researchers
The Netherlands	Non-obligatory (depends on institutions; there are some mandatory training courses for PhD students and some elements of RI are part of university educational programs)	Lectures, seminars, train-the-trainer programs, forums	Undergraduate students, PhD students, researchers

MOOC – Massive Open Online Courses; RE – Research Ethics; RI – Research Integrity; RCR – Responsible Conduct of Research

RI and RE dialogue and communication

For this framework element of the, the information on whether research and research data are usually open and whether there are existing national and institutional initiatives for making data open were collected. Further, information on whether there are initiatives aiming at informing the general public about RI issues and breaches and whether there are other initiatives involving dialogue and communication between the research community and the general public (such as science fairs that serve as a place for disseminating research among the general public and bringing science closer to the public) were obtained. Many of the analyzed countries have developed and implemented national open science and open data policies, plans, and strategies. Countries that still do not have these have some initiatives established within the research community, such as open science declarations that are adopted and promoted by universities and other research organizations. Publicly funded research organizations usually have open access policies to ensure research publications and data openness for publicly funded research. Some countries have national forums and working groups for providing recommendations and guidance on various aspects of open science. Similarly, some countries established working task forces aimed at developing implementation plans for open science. In some countries, there are initiatives for open repositories for depositing research publications and research data. Details on open science initiatives across analyzed countries are presented in **Table 5**. Regarding the process for informing the public on RI and research misconduct, this is mostly done occasionally via the lay press and mostly when it is related to publicly funded research, research fraud, and corruption. In some countries, cases of research misconduct are handled privately and the public is not informed about the outcomes. However, in some countries, anonymous statistics are available and contain data on investigations of research misconduct cases and their outcomes. The analysis also identified different initiatives across countries to bring science and research closer to the general public. In Austria and Norway, members of national academies of sciences inform the general public about important scientific insights and discoveries. In all countries included in the analysis, higher education institutions communicate research to the public, which is often done via festivals, conferences, and public meetings.

Table 5. Open science initiatives available in different European countries

Country	National open science policy/plan/strategy	Other policies and laws	Other open science initiatives
Austria	Recommendations for the Transition to Open Access in Austria 2015	Open Access Policy: Open Access to Research Data (Policy of Austrian Science Fund); Open Access Regulations of Vienna Science and Technology Fund; Many universities and institutes have open access policies	In 2012 the Open Science Network Austria was founded by Austrian Science Fund and Austrian University Conference - in charge for developing Open Access Strategy and Open Access and Open Data infrastructure; The Austrian Academic Library Consortium and the Austrian Science Fund have concluded a number Open Access agreements with the publishers; 41 multidisciplinary and discipline-specific repositories; 53 Austrian Open Access journals; Open Science Network working group organizes workshops and training session for researchers and support staff
Bulgaria	National Open Science Plan (2020)	National Strategy for Research development 2017-2030 (among strategic action point includes actions to promote and implement open science initiatives); National Strategy for Development of Scientific Research in Bulgaria 2017; National Roadmap for Research Infrastructure 2017-2023	Network of Open Access Centres (established by the Bulgarian Academy of Sciences; provides support for organizations and researchers and organizes annual information days on open access); Bulgarian Academy of Sciences promotes open access policies regularly through conferences and meetings; some universities have open access repositories and at the national level there is the Bulgarian Portal for Open Science and the National Repository for publicly funded research; Bulgarian OpenAIRE Repository (for ERC funded FP7 projects in Bulgaria)
Croatia	No national policy/plan/strategy	Croatian Open Access Declaration (supported by 19 institutions);	National repository infrastructure DABAR

		Croatian Act on Scientific Activity and Higher Education (all higher education theses digital versions must be archived in library repository); The Croatian Research and Innovation Infrastructure Roadmap 2014-2020 (addresses the promotion of open access to scientific publications)	(compatible with Open AIRE Guidelines); Portal of Croatian Scientific and Professional Journals (open access publishing platform); Croatian Scientific Bibliography CROSBI (oldest OA repository; gathers information on publications published by Croatian authors)
Country	**National open science policy/plan/strategy**	**Other policies and laws**	**Other open science initiatives**
Denmark	National Strategy for Open Access 2018-2025	Some public and private funders have open access policies	Open Access Indicator (produced annually by the Danish Agency for Higher Education; monitors the implementation of the Danish Open Access Strategy; All universities have Open Science Support Unit at university libraries
Estonia	No national policy/plan/strategy	Open Science Expert Group of the Estonian Research Council Principles and Recommendations for Developing National Policy 2016; Roadmap for an Open Science Policy Framework (Ministry of Education and Research)	University of Tartu hosts Open Access weeks since 2010 for promoting open access and open research data; University of Tartu host various training courses that include open science (Introduction to Information Research, Research Data Management and Publishing, Research Integrity)
Finland	Open access to scholarly publications – National policy and executive plan by the research community in Finland 2020-2025	Declaration for open science and research 2020-2025; Good practice in research evaluation – Recommendation for the responsible evaluation of a researcher in Finland 2020; Recommendations on Open Access to scholarly publications for research organizations (2020); Recommendation for publishing open educational resources (2020); Some funders have open science and open access policies	Open Science activities are coordinated by the Federation of Finnish Learned Societies; Every university has Open Science Support Unit at libraries; National open science courses are held
France	National Plan for Open Science 2018	French Law for a Digital Republic Act (2016; one article concerns scholarly	Science Ouverte France (dedicated open access website for researchers);

		communication and relates directly to open access/open data); National Research Agency (ANR) Open Science Policy	Doranum (website for researchers for research data); Revues platform (hosts 192 open access journals); Hyper Articles en Ligne (national centralized repository)
Country	**National open science policy/plan/strategy**	**Other policies and laws**	**Other open science initiatives**
Greece	National Plan for Open Science 2020	Law 4310/2014 (supports open access for publicly funded research); Some universities adopted open access policies; Declaration on Open Access in Greece	National Open Science Task Force (produced National Open Science Plan; National Archive for PhD Theses (access to PhD theses from all higher education institutions in Greece; Athena Research and Innovation Center (webinars and training courses on open science); HEAL-Link (supports green open access for preprints in institutional repositories)
Ireland	National Principles on Open Access 2012	National Framework on the Transition to an Open Research Environment (published by National Open Research Forum; presents goals for enabling open access to research publications, FAIR research data, developing infrastructure for open access, building skills and competences, creating incentives for open science); Some funding agencies and universities have open access policies;	RIAN (national portal for open access); Open access repositories are available at all universities; Dublin City University Press (open access university press); National Open Research Forum (supports researchers and organizations in open science); Open Knowledge Ireland (non-profit organization that promotes open data open content)
Lithuania	No national policy/plan/strategy	Guidelines on Open Access to Scientific Publications and Data (adopted in 2016 by the Research Council of Lithuania); Law on Higher Education and Research of the Republic of Lithuania (publicly funded research must be announced publicly); Some research institutions have open science policies	Electronic Academic Library of Lithuania (eLABa) (national open access repository); National Open Access Research Data Archive (free and unrestricted Internet access to research outputs)
Luxembourg	Common principles on Open Access 2015	Luxembourg National Research Fund (requires funding projects' publications to be open access; provides	University of Luxembourg repositors ORBilu;

		reimbursement of open access publishing costs); University of Luxembourg Open Access initiative (requires all university members to deposit electronic copies of published manuscripts in the institutional repository and to deposit the bibliographic references of all scientific production)	Open Science Forum (educational seminars and practical sessions); Open Science Quest (organized within Luxembourg Learning Centre for interactive sessions about open science practices)
Country	**National open science policy/plan/strategy**	**Other policies and laws**	**Other open science initiatives**
Moldova	The National Strategy for the Development of the Digital Moldova Information Society 2020	The Declaration on Open Science in the Republic of Moldova (2018; the government approved the Declaration and identified open science as a priority); 11 institutions adopted open access policies; 12 institutions launched open access repositories	The National Bibliometric Tool (digital repository for storing, classifying, and measuring publication data in national journals); Optimizing Scholarly Communication in Moldova project (promoting and advancing national and institutional open science guidelines, policies, and incentives); National Scientific Conference on Open Science (first held in 2018)
Norway	National goals and guidelines for open access to research articles 2017	National strategy on access to and sharing of research data 2018; Long-term plan for research and higher education 2019-2028 - Meld. St. 4. White paper (technology initiatives - e-infrastructure for open research); All universities and most of the other research organizations have open access policies; Digitalization strategy for the higher education sector 2017-2021 (strategy for open access to research data; resources for calculation, analysis, storage, data curation, and communication; digitalization for cost-effective management of research publications)	Official Norwegian Report NOU 2015:5 MOOCs for Norway New digital learning methods in higher education; Research output is reported in national Cristin system; National Library of Norway (digitalization of entire collection); Norwegian open research archives (harvests all institutional repositories); Open Access to research web page (providing information and promoting open science)
Spain	State Plan for Research, Development, and Innovation 2017-2020	Act 14/2011 (researchers must deposit final publications in an open access repository - for	RECOLECTA (gathers all national scientific repositories in one place);

		publicly funded research and research organizations)	Spanish Foundation for Science and Technology (provides training and workshops for researchers, librarians, policymakers; organizes national workshops) up to 57 universities and other research organizations have institutional open access repositories; Network of Spanish University Libraries (supports and promotes open access through organized events and educational courses)
Country	**National open science policy/plan/strategy**	**Other policies and laws**	**Other open science initiatives**
Sweden	No national policy/plan/strategy	Proposal for National Guidelines for Open Access to Scientific Information (2015; Swedish Research Council); Swedish Research Bill (2016; publicly funded research should be open access); Most of the funding organizations have open access policies (mandating open access to publications for research performing organizations); All universities have policies recommending publishing research results in open access	National Library of Sweden coordinates implementation of open access to publications; Swedish Research Council coordinates implementation of open access to research data; Almost all universities have open access repositories; Swepub (search service for harvesting publications from institutional repositories)
The Netherlands	National Plan Open Science 2017	Public funders have open access to publications policies	National Platform Open Science; SURF (collaborative organizations for universities and research institutes); All universities have repositories; NARCIS (central portal for repositories); The national open access website (provides information and news on open access across different universities); Open Access Week (educational courses, seminar and symposiums for promoting open science); Research Data Netherlands (provides courses for storing and preserving data)

ANR – French National Research Agency; ERC – European Research Council; CROSBI – Croatian Scientific Bibliography; MOOC – Massive Open Online Courses; OA – Open Access

Incentives

This category of country report cards captured information related to the awards and other incentives for research organizations and individual researchers based on the research output and for collaborative science and research networks. The information on whether there are any incentives for RI was also explored.

Awards and prizes for outstanding research contributions and innovations exist in every country included in this analysis. Research organizations or governments often award annual awards for promoting research and innovation. Awards and scholarships are also often provided for early career researchers to establish their first collaborative networks and projects early in their careers. Some countries have special tax schemes for encouraging research activities. For example, Austria has a lower tax scheme for those who conduct research in the country, while Denmark has a special tax scheme for researchers recruited from abroad. France has a research tax credit that supports research and development activities by providing tax assistance, and Lithuania, Norway, and Spain also have some forms of tax relief for the research and development sector.

Collaboration initiatives exist in almost all countries included in the analysis. Some countries are focused on promoting intensive collaboration between research and business sectors by providing funding to research-industry collaborative projects (e.g., Austria, Ireland, Luxembourg, Norway) or creating national initiatives to encourage the industry to engage in more research with researchers. Regarding the latter, an example is Lithuania, in which the Ministry of Higher Education and Science 2010 allocated funding to support the employment of researchers in industry and business enterprises. Besides the collaboration between research organizations and industry, all countries offer various incentives for collaboration between research institutions, and especially international collaborations. Some initiatives include paying membership fees in international societies as the Academy of Finland does it, the Baltic Bonus scheme to promote cooperation between Lithuania, Latvia, and Estonia, and the France "Setting Up European or International Scientific Networks (MRSEI)" (166) that supports the

networks coordinated by French researchers and encourages their participation in European and international projects.

Information on incentives for RI was explored in the context of quality assessments. In some countries, RI is considered in the organizational quality assessment processes. However, for most of the countries, we were unable to find information. Examples include Austria, where RI is a part of quality assessment in some institutions (e.g., the Ombudsman Office at the University of Vienna is under the coordination of the Unit for Quality Assurance). RI is part of the institutional quality assessment in Denmark as all research institutions had to adopt the Danish Code of Conduct for RI. In Finland, RI is introduced as a part of institutional quality assessment, and universities have to organize international research assessments every six years to measure the quality of research.

4.2. Scoping review on the existing research integrity documents available in biomedicine and other disciplines

4.2.1. Search and flow diagram

The initial search of bibliographic databases Medline, WoS (Core Collection), Scopus, and PsycINFO retrieved 32,887 publications. After removing duplicates, 26,805 publications remained for the title and abstract screening. After screening titles and abstracts, 130 documents were left for the full-text assessment. In the following step, during the full-text assessment, 73 documents were excluded, which left 57 documents for the final analysis and data synthesis. Most of the excluded documents were excluded because they were not related to guidance documents or did not contain any description or details on the guidance documents, as was set in the eligibility criteria. Another reason for exclusion was the inability to find publications in the full-text format required for the analysis (n=5). The screening of the references from the 57 publications included in the final analysis identified additional 35 publications, which were mostly grey literature, i.e., codes and guidelines provided on the websites of research performing and research funding organizations, or other professional organizations, while one publication was a journal publication (a commentary). Hence, the total number of publications included in the analysis was 92. The search of the grey literature sources retrieved 118 publications, hence the final number of publications both peer-reviewed and from grey literature sources, that were included in the analysis was 210. The three-step screening methodology process and the number of publications relevant to each screening phase are presented in **Figure 2**.

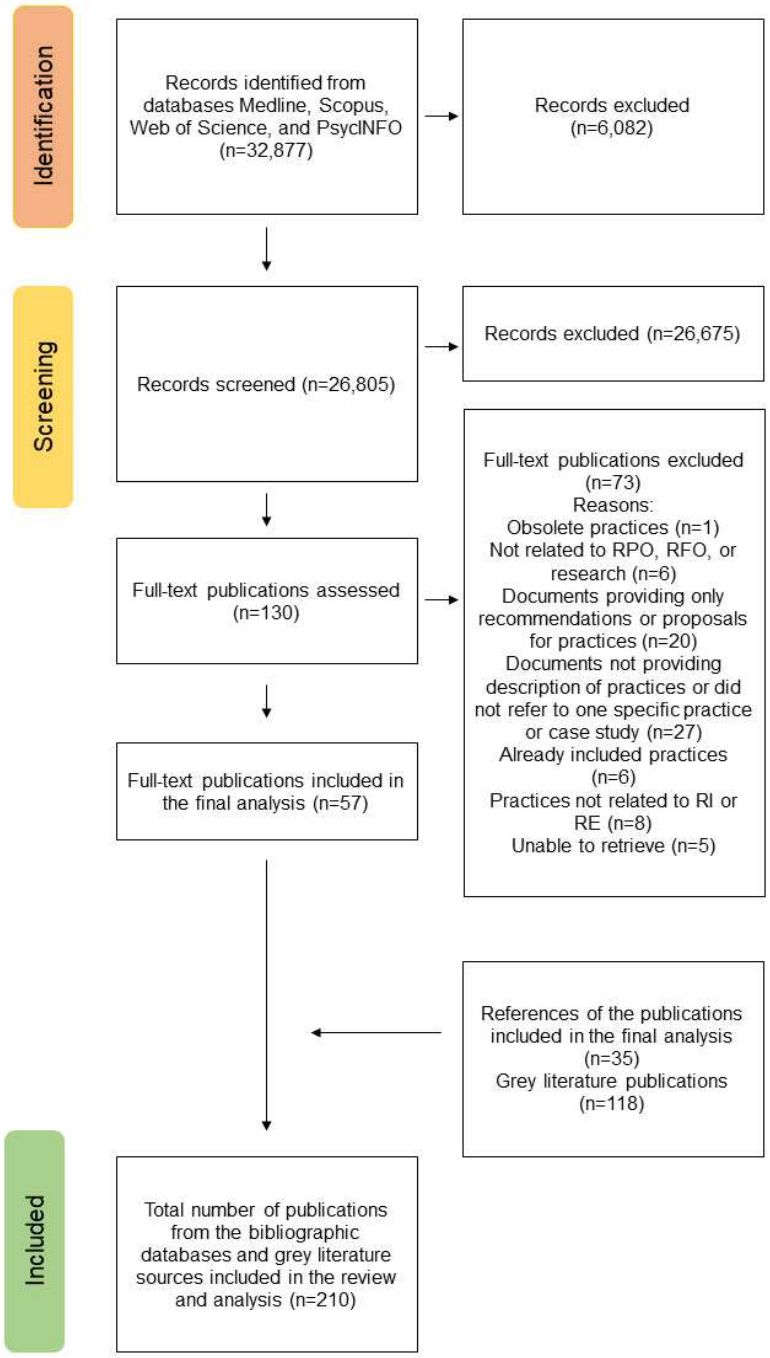

Figure 2. PRISMA-ScR flow diagram for the scoping review process. RE – research ethics; RI – research integrity; RFO – research funding organization; RPO – research performing organization.

4.2.2. Characteristics of included evidence

Origin of RI Practices

The largest number of analyzed publications was related to RI guidance documents from the USA (n=65/210, 30.9%). This was followed by the guidance documents developed by international organizations or projects and not aimed or developed by a specific country or countries. Instead, these documents could be applicable internationally (n=50/210, 23.8%). For example, publications mapped as of international origin were Responsible Conduct in the Global Research Enterprise: A Policy Report by Inter Academy Council and the Inter Academy Partners (167), World Health Organisation Guidelines for Good Clinical Practice for Trials on Pharmaceutical Products (168), European Science Foundation Good scientific practice in research and scholarship (169), and the Hong Kong Principles for Assessing Researchers: Fostering Research Integrity (54). Some publications referred to and described guidance documents from more than one country, i.e., two or more countries were explicitly mentioned. In these cases, all countries mentioned were included in the analysis. The origin of RI guidance documents by a country identified in this study is presented in **Figure 3**.

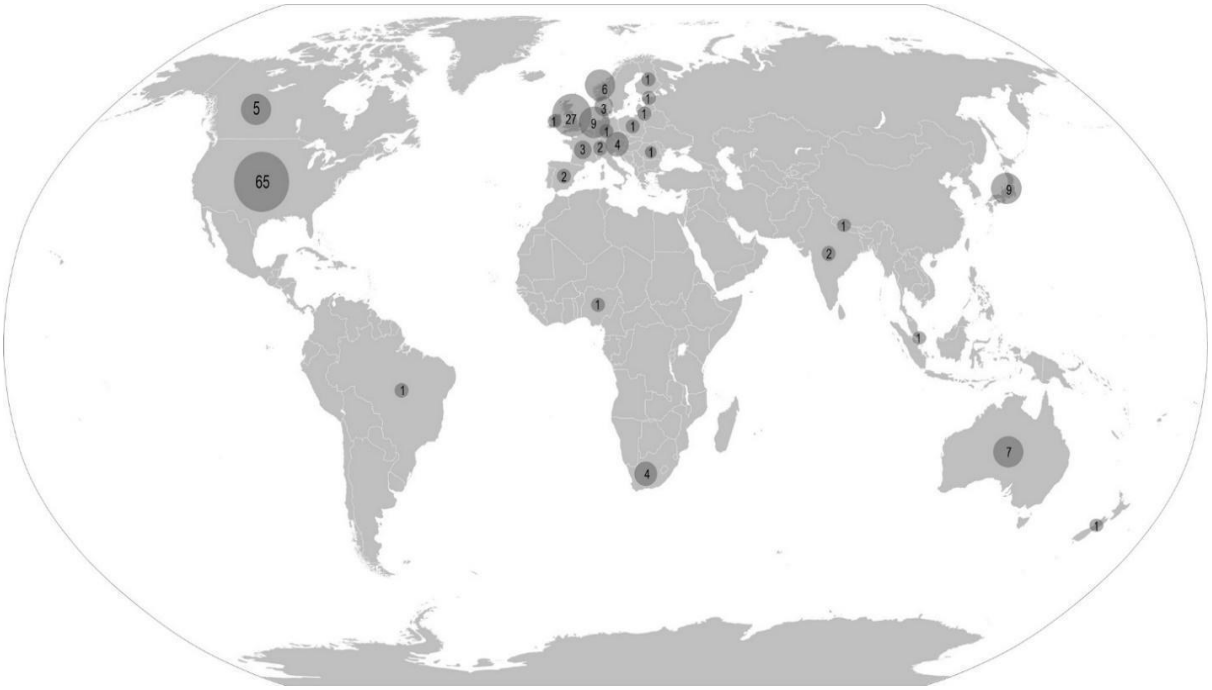

Figure 4. Origin of practices by country (without international practices; number of international practices n=50). The United States of America (n=65), United Kingdom (n=27), Japan (n=9), the Netherlands (n=9), Australia (n=7), Norway (n=6), Canada (n=5), Austria (n=4), South Africa (n=4), Denmark (n=3), France (n=3), India (n=2), Spain (n=2), Switzerland (n=2), Brazil (n=1), Estonia (n=1), Finland (n=1), Germany (n=1), Ireland (n=1), Lithuania (n=1), Nepal (n=1), New Zealand (n=1), Nigeria (n=1), Poland (n=1), Romania (n=1), Singapore (n=1).

There were 50 documents which were international and could not be located in a single country.

Source for the geographical map: https://commons.wikimedia.org/wiki/File:BlankMap-World.svg (public domain)

Regarding the disciplines, most guidance documents referred to RI issues and practices that are not related to any specific discipline but referred to research in general (n=108/210, 51.4%), followed by RI guidance in biomedicine (n=78/210, 37.1%). For social sciences, 10 (n=10/210, 4.8%) RI guidance documents were identified, same as for the natural sciences (n=10/210, 4.8%). For humanities, 4 guidance documents were identified (n=4/210, 1.9%). Some of the analyzed publications referred to RI guidance documents from multiple disciplines;

in these cases, all disciplines addressed were counted. Regarding the organizational origin, most of the identified guidance documents were related to research performing organizations (n=150/210, 71.4%). Although some guidance documents related to research performing organizations were related to funding organizations as well, these practices were considered to be primarily intended for research performing organizations since the guidance addressing funders was only briefly mentioned. Documents addressing equally research performing and funding organizations were also identified (n=54/210, 25.7%) together with the documents addressing research funding organizations (n=6/210, 2.9%) explicitly.

Type of guidance documents

Based on the distinction between the types of guidance documents, the study identified 11 different types of guidance documents. Guidelines were most prevalent (n=136). Other types of guidance documents included codes (n=35), policies (n = 26), legal documents (n = 14), reports (n = 10), checklists (n = 9), statements (n = 6), declarations (n = 4), flowcharts (n = 2), white papers (n = 1), and standard operating procedures (n = 1). It is important to mention that some publications referred to more than one type of guidance document; in these cases, each type of guidance document was counted and mapped. For this reason, the presented numbers are higher than the number of publications included in the final analysis. Different guidance documents were analyzed over three periods: 1990–1999, 2000–2009, and 2010–2019 (**Figure 4**). Most of the identified guidance documents dated from 2010 onward, and regarding the type of guidance documents, guidelines were mostly represented throughout all three time periods. For some guidance documents the exact time they were developed could not be identified, hence these documents were not included in the analysis (n=11).

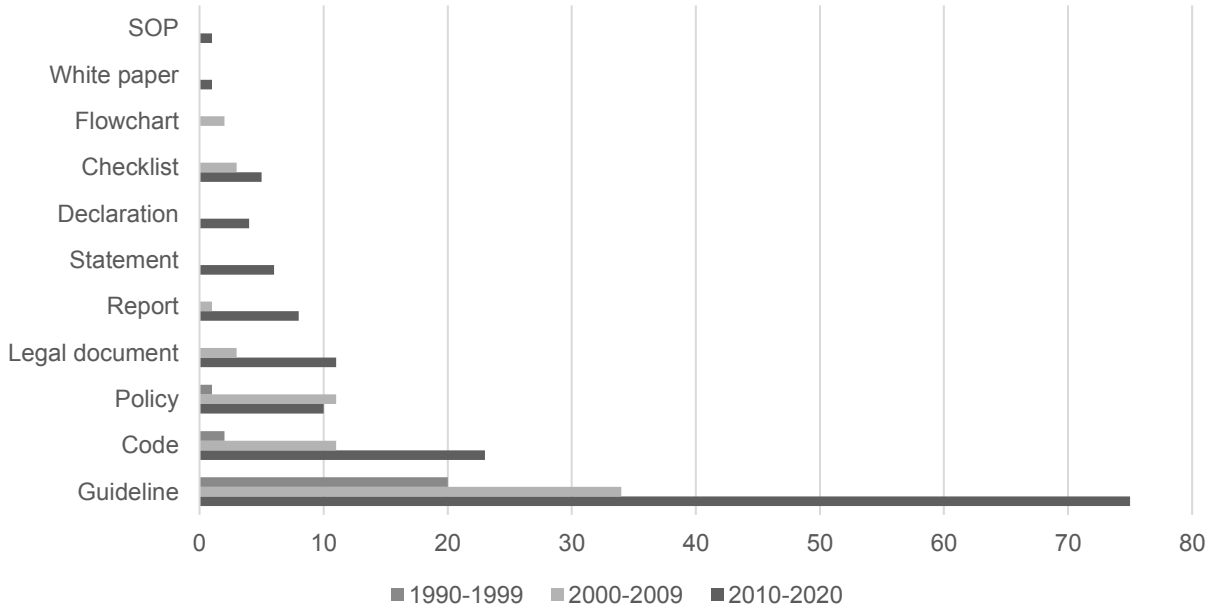

Figure 5. The number of guidance documents in different time periods. The x-axis shows the number of guidance documents, and the y-axis lists different types of guidance documents. SOP – standard operating procedure

Target group to which guidance documents were directed

RI guidance documents addressed both individuals and research organizations as target groups (**Table 6**). For the analysis identified stakeholders were grouped into five main categories – researchers, research performing organizations, research funding organizations, RE and RI bodies, and other policymakers. Most of the guidance documents referred to more than one category, i.e., provided RI guidance for multiple stakeholders.

Table 6. Individuals and organizations addressed in RI guidance documents

Individuals and organizations by category and sub-category	No. of documents
Researchers (including research groups, students, mentors and supervisors, reviewers, whistle-blowers)	167
RPOs (including administrators)	111
Research integrity and research ethics bodies (REC, RIC, research councils, IRB, RIOs, RIAs, Ombudsman)	51
RFOs	41
Policymakers	41

IRB – institutional review board; REC – research ethics committee; RI – research integrity; RIA – research integrity advisor; RIC – research integrity committee; RIOs – research integrity offices/officers; RFOs – research funding organizations; RPOs – research performing organizations

4.2.3. Research integrity topics presented in guidance documents

For his point of analysis, guidance documents were classified according to the different steps of the research process – planning, conducting, disseminating, and evaluating research. Moreover, two additional categories were RI violations and resolutions and RI promotion. These two additional categories were introduced because they are relevant for all phases of the research process but still contain important aspects of RI that are often handled separately and independently outside of some specific category. The main categories were further broadened by the list of RI-related topics that were mentioned in the analyzed documents. For example, the category of RI violations and resolutions comprised RI guidance documents that addressed research misconduct investigations, sanctions, and others, while the category of RI promotion comprised documents related to the development and implementation of RI guidance, implementation of RI training, and establishment of bodies for RI promotion. Some topics were related to more than one research process. The analysis addressed which of the extracted topics were related to research organizations. These guidance documents reflected on the organizational procedures and measures that could be implemented for individual researchers and for RI improvement in general. A Map of the guidance documents by research processes phases and topics, intended for organizations and policymakers, is available in **Appendix 6**,

while the map of guidance documents intended for individual researchers is available in **Appendix 7**.

4.2.4. Principles addressed in guidance documents

Some of the guidance documents that were included in the analysis contained fundamental guiding principles that researchers and organizations should follow (n=28). The principles were extracted and matched to those outlined in two major policy documents – the European Code of Conduct for Research Integrity (the ALLEA code) (37) and the National Academies of Sciences, Engineering and Medicine (NASEM) book Fostering Integrity in Research (3). The comparison of fundamental principles is available in **Appendix 8.**

4.3. Scoping review on the individual, organizational, and systemic factors influencing the implementation of research integrity in biomedicine and other disciplines

4.3.1. Search process and flow diagram

The search of bibliographic databases retrieved 32,887 publications, and after removing duplicates, 26,805 publications were left for screening. In the next step (screening of titles and abstracts) 254 publications were excluded. The final analysis and data extraction included 132 publications. The reference search of the included publications yielded 43 additional publications that were included in the full-text analysis. Since the search was updated, the updated search of bibliographic databases retrieved 9,084 publications. After screening titles and abstracts, 83 publications were included in the next analysis step. In the end, 40 publications were left for final analysis and data extraction.

The search of grey literature sources retrieved 21 publications. Hence, the final number of all analyzed publications was 236. The process from identification to including the publications, in the final analysis, is presented in PRISMA ScR-flow diagram (**Figure 5**).

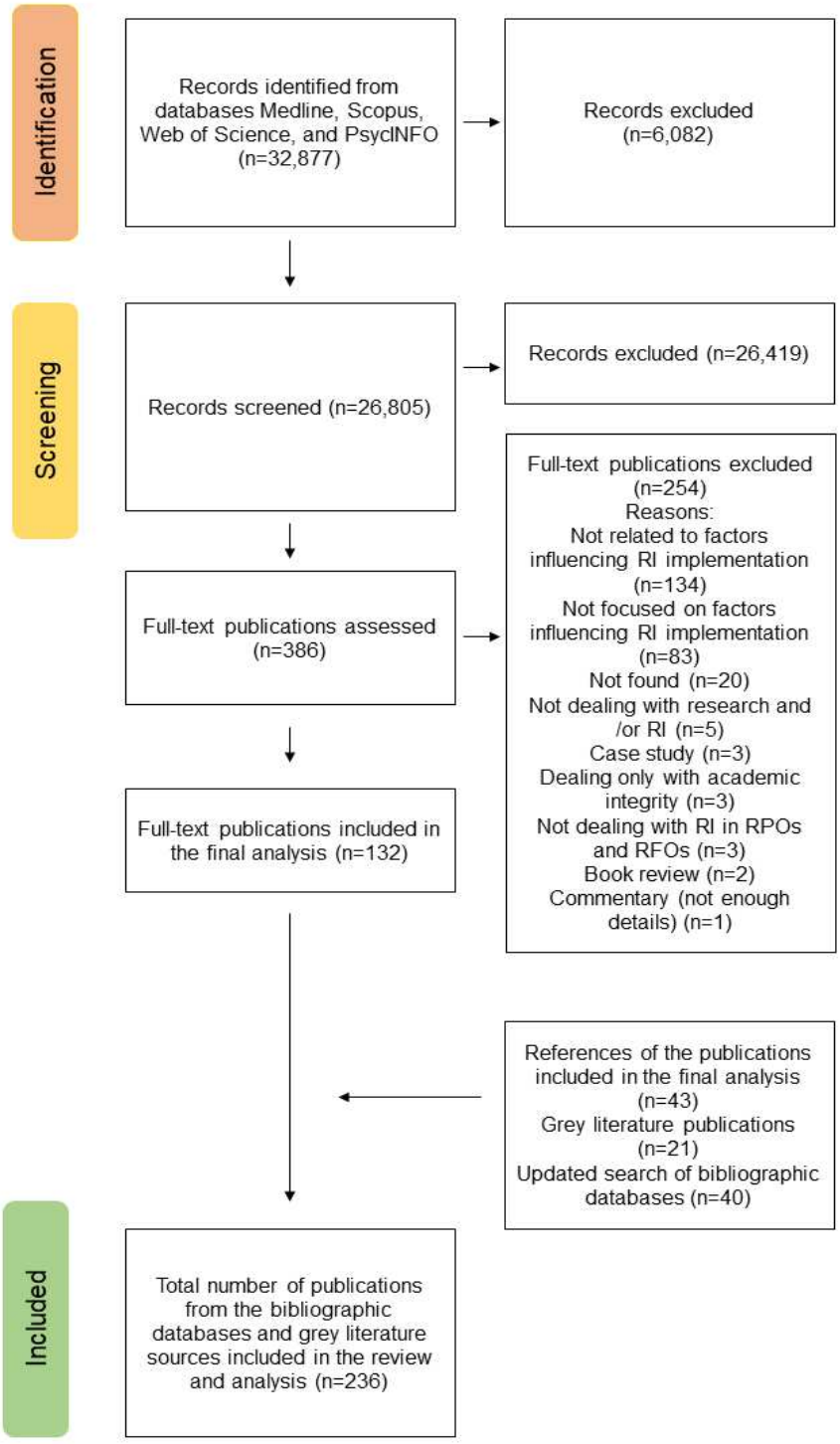

Figure 6. PRISMA-ScR flow diagram for the scoping review process. RE – research ethics; RI – research integrity; RFO – research funding organization; RPO – research performing organization

4.3.2. Characteristics of included evidence

The majority of publications included in the final analysis were journal articles (n=203/236, 86%), followed by conference materials (n=16/236, 6.8%), book sections (n=8/236, 3.4%), books (n=5/236, 2.1%), and reports (n=4/236, 1.7%). Most publications were related or originated from the USA (n=98/236, 41.5%), while 43 (n=43/236, 18.2%) publications were marked as "international" (publications that were not related to any specific country or countries but were more focused on RI on a global level or a certain geographic area, e.g., Europe). Most publications were related to or originated from biomedical sciences (n=115/236, 48.7%) or were related to research in general (n=102/236, 43.2%). Moreover, the majority of publications were related to research performing organizations (n=197/236, 83.5%). Regarding the publication period, 16 publications were dating from 1990 to 1999 (n=16/236, 6.8%), 52 were published from 2000 to 2009 (n = 52/236, 22%), and 150 publications from 2010 to 2019 (n = 150/236, 63.6%). In the period from 2020 to 2021, 18 publications were identified (n = 18/236, 7.6%).

Among the journal articles (n=203), the majority were reviews, perspectives, and opinions (n=75/203, 36.9%). Concerning the methodological approaches of the studies, 66 studies were quantitative (n=66/203, 32.5%), 35 were qualitative (n =35/203, 17.2%), and 9 mixed-methods (n= 9/203, 4.4%) studies, as well as 18 commentaries and editorials (n=18/203, 8.9%). The majority of quantitative studies were surveys and questionnaires (n=62/66, 93.9%), while a few studies were systematic reviews (n=3/66, 4.5%), and meta-analyses (n=1/66, 1.5%). Qualitative studies were mostly semi-structured interviews. As for the funding sources, journal articles (excluding commentaries and editorials) reported public (n=72/185, 38.9%), public and nonprofit (n=8/185, 4.3%), and nonprofit funding (n=3/185, 1.6%). Moreover, 11 journal articles reported not receiving any funding for research (n=11/185, 5.9%), and in almost half of all articles, there were no disclosure regarding funding sources (n=91/185, 49.2%).

4.3.3. Factors most often mentioned across publications

The factors that were most often mentioned across publications included in the analysis and referring to the level of individual researchers, organizations, and systems of science are presented in **Table 7** below. The full taxonomy of factors and a list of publications in which

factors were identified are presented in **Appendix 9**. In the next section, a brief description of the most often identified factors for each level is described.

Table 7. Taxonomy of factors most often mentioned across publications included in the analysis

Level: Individual researcher		
Environment and culture	**Positive**	**Negative**
	The role of mentors, supervisors, and senior researchers (role models); Culture of open communication, dialogue, justice, and integrity	The role of mentors, supervisors, and senior researchers (negative role models); Precarious position of junior researchers (e.g., power imbalance between junior and senior researchers); Perverse incentives; Pressure; Situational factors (e.g., financial and relationship issues); Lack of protection for whistleblowers; Environment and culture differences (e.g., existence of various rules and differences between rules; different interpretation of guidance in different setting); Lack of independence from industry (e.g., industry funds research, or training and education)
Personality traits, personal values, aspirations, and motivation	**Positive**	**Negative**
	Positive personality traits (e.g., high moral integrity, honesty, sense of social responsibility, respectfulness); Willingness to report misconduct and other scientific dishonest behavior; Willingness to disclose conflict of interest	Negative personality traits (e.g., vanity sloppiness, greed, Machiavellianism, etc.); Wish for recognition, success, and financial gain; Taking RI for granted; Not declaring conflict of interest (related to career benefits and financial gain); Not reporting misconduct (e.g., because of the fear of consequences)
Knowledge and skills	**Positive**	**Negative**
	Having research experience, good knowledge and understanding of research and RI; Completing RI or RCR education; High awareness of the importance of RI	Lack of RI or RCR education; Lack of knowledge on RI, RI policies and procedures; Not knowing or recognizing responsibilities (lack of experience)
Level: Research organizations		

Research environment and culture	**Positive**	**Negative**
	Fostering a culture of integrity, transparency, deliberation, compliance, collaboration and inclusivity; Good ethical climate and organizational justice; Creating safe and trusty environment for discussing RI issues; Raising awareness on RI and research misconduct; Responding to misconduct cases; Promoting transparency (publishing incidence of research misconduct and other detrimental research practices)	Poor organizational climate, governance and leadership; Lack of positive organizational values; Focusing on profit and money, productivity and performance; Competitiveness between academic institutions; Lack of independence from industry (organizational conflict of interest); Avoiding to investigate misconduct
Research integrity education and support	**Positive**	**Negative**
	Providing education on RI issues and for different groups of researchers; Implementing RI training into curriculum	Lack of RI and RCR training in the organization (or lack of effective education)
Research integrity policies, structures and processes	**Positive**	**Negative**
	Developing, implementing, and updating RI policies and guidance documents; Monitoring researchers' compliance with RI policies and guidance documents; Having adequate bodies to deal with RI and research misconduct issues; Developing strategies to mitigate and resolve disputes; Implementing sanctions for research misconduct; Developing a program for the whistleblowers' protection; Developing a comprehensive plan to promote RI	Lack of RI policies and guidance documents; Lack of clear, detailed and uniformed RI policies and guidance documents; Lack of sanctions for research misconduct
Evaluations, incentives, and rewards	**Positive**	**Negative**
	Putting focus on quality of research and scientific process instead of prestige, ranking and financial gain; Evaluating and awarding research based on research integrity requirements	Performance based evaluations (e.g., performance related salaries and perverse incentives; valuing quantity of research instead the quality)
Research integrity in funding organizations	**Positive**	**Negative**
	Developing and implementing policies and procedures for RI promotion and investigation of research misconduct; Funding and evaluation criteria (putting more emphasis on RI)	Evaluations based on research topic attractiveness rather than on quality of research (output oriented funding)
Level: System of science		
	Positive	**Negative**

Global research culture	Research metrics (valuing quality over quantity); Reducing over-competitiveness Establishing a common system for dealing with RI and research misconduct (having national, independent bodies for research integrity training and misconduct investigations)	Pressure to publish; Focus on competition and productivity; Differences between countries and disciplinary fields in defining poor research behavior
Scientific journals and publishers	**Positive**	**Negative**
	Having clear policies and procedures for RI issues; Implementing practices for research misconduct (e.g., retracting fraudulent publications, informing research organizations about suspected misconduct, cooperating with research organizations in investigations)	Lack of enthusiasm to publish negative research results

Individual factors addressed in publications

Most of the analyzed publications addressing factors related to individual researchers focused on the factors that negatively impact the promotion and implementation of RI and RI guidance documents. One of the prominent factors that was often mentioned was the influence of research supervisors and mentors. Supervisors and mentors can influence and shape early career researchers' behavior, which can go two ways. Either supervisors and mentors act like role models by respecting RI standards in their work, and by spending enough time with supervised students to guide them on responsible research practices (which is seen as a factor that positively influences RI promotion and implementation); or they act as negative role models due to the lack of skills or perhaps because they are overworked with their job and supervising responsibilities, or they are uninvested in RI (102, 116, 117, 119, 170–173). Regarding the individual factors, some of the analyzed publications explored the role of researchers' personality on research behavior. These publications indicate that different personality traits are often related to how researchers think, feel, behave, and cope with a pressuring academic environment. Negative personality traits, such as narcissism, egoism, self-entitlement, or negligence, might be related to researchers not adhering to the RI policies and standards in their work (64, 114, 174, 175). On the other hand, having high moral values such as honesty, respect toward others, and awareness of social responsibility is often related to putting more emphasis on standards and rules, including those concerning RI (170, 176). Further, negative personality

traits are often related to different desires, such as the desire for recognition and success, the desire for fame, and financial gain, which may mean that researchers scoring high on specific negative personality traits could break the rules more often to achieve their research and career goals (66, 177). The analyzed publications also mention external factors that influence individual behavior. The publish or perish and influence of commercialized research, perverse incentives, the pressure to publish in high-impact factor journals, as well as pressure to obtain funding and tenure were often mentioned across publications as negative factors (173, 178–181). On the other hand, changing research metrics requirements, evaluation system, and award structures by emphasizing RI and quality of research instead of its quantity is seen as a solution to ease the pressures that researchers are exposed to, and that may negatively influence their honesty and responsible research behavior (118, 182, 183). Another often mentioned external factor influencing researchers' adherence to RI is the willingness to report research misconduct and other detrimental research practices. In many cases, breaches of RI go without sanctions which may encourage others to involve in research misconduct or other detrimental research behavior and, at the same time, discourage those who pursue their academic career with integrity from reporting the breaches to the dedicated bodies (19, 179, 184). In some cases, it could also be that researchers are not willing to report misconduct because they do not trust the system and are afraid of possible consequences for their career, as adequate support for whistleblowers is often lacking (119, 182, 184–186). Further, researchers' willingness to actively pursue RI standards in practice was often mentioned in the context of conflict of interest. In many cases, researchers do not disclose conflict of interest they may have because the conflict benefits them (as previously mentioned due to the commercialization of research and opportunities for financial gain), or they lack awareness and knowledge of what constitutes a conflict of interest, as well as why and how to disclose it (180, 187). On the other hand, disclosure of conflict of interest was mentioned in the context of factors that promote and foster research integrity standards (187–189). Most publications related to factors at the level of individual researchers were included in the topic related to researchers' knowledge and skills. Research and RI experience, often obtained through RI education, were seen as factors that could facilitate and promote RI. Undergoing RI education and training was seen as a positive factor or perhaps the first step in encouraging researchers to adhere to RI standards in their work. Moreover, RI education is considered to benefit the researchers by helping them develop knowledge and

awareness of RI and research misconduct, knowledge on how to act in challenging situations related to RI, and the awareness of how RI is important for science (183, 190, 191). Similarly, the lack of RI education and training were seen as factors that hindered the promotion and implementation of RI in their research work. Nevertheless, it is important to mention that not all studies included in this analysis explored whether interventions related to RI education are effective. Some studies that explored the effectiveness of RI interventions, including those related to RI education, are included in the critical appraisal analysis conducted as a part of this scoping review.

Organizational factors addressed in publications

Similar to the level of individual researchers, at the organizational level, publications were categorized based on the positive and negative factors into five main categories (**Table 7**). In the topic related to the organizational research environment, publications most often referred to the organizational climate that can be perceived as ethical or unethical. Ignoring the issues related to the organizational research climate was seen as a major problem that hinders the implementation of RI at the organizational level and the level of individual researchers. This is often because the organization's policies, practices, and ethical climate shape researchers' behavior and attitudes (115, 118, 192). As the organizational culture that can positively influence researchers' behavior is perceived the one that focuses on integrity, transparency, collaboration, and inclusivity in which RI is promoted, while cases of research misconduct are properly handled (31, 118, 192). On the other hand, if the organization is too invested in competitiveness and rankings at the cost of denying, ignoring, or even covering up research misconduct to preserve reputation, an unhealthy research environment is created; the environment in which researchers may be prone to avoid rules and good practices (119, 193, 194). One way of contributing to the development of good organizational culture, often mentioned as publication as a factor that can have a positive impact on RI promotion and implementation, is having in place codes of conduct and other policies and regulations for RI, as well as comprehensive plans on how to promote RI within organizational structures. Further, it is considered important to have adequate RI bodies in place as a factor with the positive impact. These could be administrative bodies that will be handling cases of research misconduct and other detrimental research behavior. However, besides only establishing these bodies, it is important to ensure that the work of these bodies is effective in practice. In order to achieve that,

organizations should ensure that personnel working in the RI bodies undergo adequate training and that there are adequate guidelines and procedures in place describing how these bodies work (195, 196). Another important topic developed at the organizational level of analysis is the topic of RI education. Publications related to this topic emphasized the important role of research organizations in ensuring the establishment and organization of RI educational courses and training for researchers. A comprehensive effort in this area would be implementing research integrity training into the curriculum (197, 198). Further, at the organizational level, some of the included articles referred to the funding organizations, and several factors with negative impacts were emphasized. These include, for example, so-called output-oriented funding in which funders provide grants based solely on the attractiveness of research rather than its quality (19, 199). Given that research grants have a huge impact on researchers' careers and the visibility of research results, funders should employ proper measures that will ensure greater applicability of RI standards when providing research funds (47, 200). These may include, for example, funders developing and implementing obligatory RI and research misconduct policies more often and putting more emphasis on RI when evaluating research and projects' proposals (201–203).

Factors related to the system of science addressed in publications

At the system of science level, relevant publications addressing factors with a positive or negative impact on RI were categorized into two main topics – global research culture and scientific journals and publishers (**Table 7**). The majority of publications addressed factors that have a negative impact on RI. Many of these publications focused on the pressures and trends in academia, as well as efforts to make changes in how research is evaluated on a global level. Currently the research system is pervaded with a focus on productivity, competition, the quantity of research and research publications. Publications included in this review, as a positive initiative, propose a change in how scholarly work is evaluated and considered when it comes to career promotions, awards, and winning research grants. Relying on a single metric when evaluating research, for example, on impact factors, should be replaced with introducing more qualitative metrics into the evaluation system. This also means including more RI standards and metrics into evaluations (120, 198). For example, these could include emphasizing the methodological quality of research publications or evaluating researchers' adherence to open science initiatives, such as publishing in open access, publishing preprints, and giving access to

research data. Differences that exist between countries and disciplinary fields in research, especially in the area of defining what detrimental research practice is, were mentioned across analyzed publications as a prominent issue that has a negative impact on the promotion and implementation of RI (38, 180, 204, 205). In order to combat these flaws of the current research systems, publications emphasized the need for harmonizing RI policies by adopting common definitions and frameworks of basic RI concepts, as well as establishing common procedures for dealing with RI issues (190, 206). At the system of science level, scientific journals and publishers and their initiatives have an important role in fostering RI. Some of these initiatives include publishing research with negative results (which is often avoided), providing more guidance for reviewers, and employing pre-registration and data-sharing practices. Moreover, scientific journals should closely work with research organizations by informing one another about suspected misconduct and cooperating in investigations (207). Regarding the factors with a negative impact related to the scientific journals and publishers, publications mostly referred to the practice of publishing only research with positive research results that will draw a lot of attention, lack of clear policies for research misconduct, and neglectful or irresponsible practices of reviewers and journal editors.

4.3.4. Critical assessment of the evidence

As described in this study's methods, critical evidence assessment was performed for this scoping review. When conducting the scoping review, critical assessment of evidence is not the essential step like it is, for example, in systematic reviews. However, taking into account the aim of this scoping review, the critical assessment of the evidence was conducted in order to have a more comprehensive approach to the field of RI interventions that affect RI promotion and implementation and to test the effect (positive or negative) and effectiveness of these interventions in practice.

Overview and characteristics of studies included in the critical assessment of the evidence

The scoping review analysis identified 10 studies related to the RI interventions. Studies were published from 2008 to 2020 and included pre-and-posttest studies (n=5) (172, 208–211), randomized controlled trials (n=2) (182, 212), pre-and-posttest with posttest only (n=1) (213), pre-and-posttest with follow up (n=1) (214), and qualitative research (n=1) (215). Population type and sample sizes varied across studies, including from 24 to 1002 participants from natural,

social, and biomedical sciences. In most studies, interventions were conducted face-to-face and included various research integrity and ethics training approaches, such as short-term training, sensemaking training, and role-play scenarios. Studies often reported limitations regarding sample size and lack of control over the test-taking environment. The main findings from these studies indicate that RI education and training are important for researchers and research as they affect awareness of good and poor research practices (211) and might increase trust among researchers (210). Moreover, sensemaking or role-play approaches to RI education seems to positively influence researchers' ethical decision process (208, 214, 215), and the role of mentors and supervisors is thought of high importance in shaping students' attitudes toward academic integrity (172). However, some studies in their results showed that responsible conduct of research education could have even harmful effects as it may encourage researchers to feel overstressed or have overconfidence in their RI knowledge and abilities (209). Another conclusion was that short-term education does not provide long-term effects and should be substituted with more concrete or periodical education (213). Further, analyzed studies reported that direct communication between researchers and research leaders in which researchers can share their thoughts on organizational climate might contribute to positive changes and improve organizational ethical climate and culture (212), as well as that incentives provided by organizations have a major role in incentivizing detrimental research behavior (182). An overview of the studies describing interventions and its characteristics are available in **Table 8**.

Table 8. Overview of characteristics of studies describing interventions for RI

Source	Study design	Study population and setting	Sample size	Interventions and delivery mode	Outcome measures	Key findings	Reported limitations
Powell, Allison, and Kalichman 2007	Pre-and-post-test and post-test only	Medical students participating in Summer Research Program which includes responsible conduct of research course.	65 (15 pre-test, 50 post-test)	Short-term responsible conduct of research training; face to face	Research ethics survey for assessing the effectiveness of a short responsible conduct of research course	Short-term responsible conduct of research education has little or no influence on improving the skills and behavior of researchers	Lack of control over test-taking environment and possible influence of other external factors on outcomes
Kligyte et al. 2008	Pre-and-post-test	Members of the large, multi-cultural, multi-disciplinary, and multi-university research center working on developing remote sensing technology for weather studies	42 (34 male, 8 female)	Sensemaking training; face to face	Ethical-decision making measure (12 scenarios addressing different disciplinary fields mapped according to 4 main domains – data management, study conduct, professional practices, and business practices)	The sensemaking responsible conduct of research training had a positive effect on researchers' ethical decision-making in data management, study conduct, professional practices, and business practices	Limited sample size (including limited sample size in pre-and-post comparison); training conducted in single research center; not clear whether sensemaking training would have an effect on other research integrity measures; follow-up was not conducted for long-term effects
Mumford et al. 2008	Pre-and-post-test design with follow up	Doctoral students working in the biological and social sciences; control group – doctoral students from the biological, health, and social sciences	59 (19 men, 24 women, 16 unreported); 245 participants in the control group (95 men, 144 women, 6 unreported)	Sensemaking training; face to face	Ethical-decision making measure	The sensemaking responsible conduct of research training led to improvements in ethical decision-making, and improvements were maintained over time	Lack of control over test-taking environment and possible influence of other external factors on outcomes; study conducted at single university and in two disciplinary fields; voluntary nature of participation
Antes et al. 2010	Pre-and-post-test	Participants in the responsible	173 (men 35%,	Responsible conduct of	Ethical-decision	Responsible conduct of	Lack of control over test-taking

		conduct of research course at US universities (students of biological, health, and social sciences)	women 58%, unreported 7%)	research educational courses; online	making measure	research education may not be effective enough and can even be harmful in some cases (e.g., leading to overstress, overconfidence and overemphasizing ethical nature)	environment and possible influence of other external factors; limited sample size for pre-post comparison; only one outcome measure
Source	**Study design**	**Study population and setting**	**Sample size**	**Interventions and delivery mode**	**Outcome measures**	**Key findings**	**Reported limitations**
Seiler et al. 2011	Qualitative study	Graduate science and engineering students.	41 (17 attended role-play session, 13 attended a case discussion session, 11 untrained); 23 men, 18 women	Role-play scenarios and "think aloud" case analysis; face to face	Analysis of interviews to assess the effectiveness of role-playing and case discussion approaches to responsible conduct of research education	Role-play approach to responsible conduct of research education may promote deeper appreciation of responsible conduct of research	Questions were broad; small sample size and age difference between participants; conducted in a single institution
Jordan and Gray 2012	Pre-and-post-test	MPhil. and PhD students participating in courses on research ethics at the University of Hong Kong	1002 participants (549 pre-test and 453 post-test)	Responsible conduct of research education; face to face	30-question survey with a Likert scale for assessing increase or decrease of the level of trust between researchers after completing responsible conduct of research education	Responsible conduct of research training may be related to students having less trust toward their supervisors and senior researchers and more trust and stronger belief in the ethical behavior of peers	Relatively small population at single institution, English language proficiency, collusion on survey responses
Gray and Jordan 2012	Pre-and-post-test	MPhil. and PhD students participating in courses on research ethics at	1002 participants (549 pre-test and 453 post-test)	Research ethics courses; face to face	30-question survey with a Likert scale for assessing the	Supervisors play an important role in shaping students'	Not reported

		the University of Hong Kong			relationship between researchers and supervisors after responsible conduct of research education	attitudes toward academic integrity; some supervisors may feel burden of mentorship	
Source	**Study design**	**Study population and setting**	**Sample size**	**Interventions and delivery mode**	**Outcome measures**	**Key findings**	**Reported limitations**
Martinson et al. 2017.	Randomized controlled trial	Research Service leaders from the Veterans Health Administration (VA) facilities	24 (21 completed follow up)	Phone-based and e-mail based report on survey results on organizational climate; online and telephone conversation	Survey of Organizational Research Climate (SOuRCe) consisted of 32 items for assessing the effectiveness of reporting the results of the survey on organizational climate to research leaders	Survey-based feedback on organizational culture does not have enough potential to incentivize positive changes in organizations, while having telephone conversations with leaders and written feedback may incentivize some positive changes contributing to better research integrity culture within the organization	Pilot project; conducted during media coverage and controversy related to Veterans Health Administration (possible impact on institutional leaders' willingness to participate in the study)
Bruton et al. 2020	Randomized controlled trial	Principal Investigators funded by the US National Institutes of Health and National Science Foundation	287 (123 men, 115 women, 4 unreported)	Short statements about research ethics; online	Narrative responses on different statements about, for example, research ethics, research misconduct, and questionable research practices; the	Institutional and career-oriented incentives may encourage the use of questionable research practices; there is a lack of confidence in the effectiveness	Extensive input from participants was not collected through reaction question hence useful feedback was perhaps missed; study design not well-structured to bring disciplinary differences in spotlight

					study also used a Likert scale in combination with open-ended questions	of ethics training in improving research behavior	
Source	**Study design**	**Study population and setting**	**Sample size**	**Interventions and delivery mode**	**Outcome measures**	**Key findings**	**Reported limitations**
Mabou Tagne et al. 2020	Pre-and-post-test	Researchers from University of Insubria, Italy (students, PhD students, clinicians, lecturers, researchers, and post-docs	65 (28 men, 37 women)	One-week intensive course on methodology, ethics and integrity; face to face	Closed-ended questionnaire based on the Scientific Misconduct Questionnaire (SMQ-R)	Research integrity training is considered important for good research and research evaluations should change by putting emphasis on qualitative rather than bibliometric criteria	Limited sample size; sample not representative; possible risk of misinterpreting questions by participants

Critical appraisal of sources of evidence

Critical appraisal of sources of evidence was performed to assess the methodological quality of studies, and the JBI Critical Appraisal Tool Checklist for quasi-experimental studies was used for analyzing the studies with the pre-and-posttest study design, pre-and posttest with the posttest only, and pre-and-posttest with the follow up (172, 208–211, 213, 214). One additional criterion was added– who created the intervention, who delivered it, and who analyzed the data – to assess the risk of bias for researchers who conducted the studies. For the randomized controlled trials included in this analysis (182, 212), the JBI checklist that consists of 13 items was used, and for qualitative studies, a checklist that consists of 13 items was used (215).

The analysis showed that all studies included in this analysis had issues related to the methodological quality in at least one category of the Critical Appraisal Tool checklist, which further implies that overall methodological quality could be improved and the effectiveness of the tested RI interventions cannot be definitely asserted. All quasi-experimental studies included in the analysis adequately reported the study aim, intervention, outcome of interest and the

connection between these (172, 208–211, 213, 214), and in most studies outcomes were measured in a reliable way (208, 209, 211, 213, 214) and appropriate statistical tests were employed for data analysis (172, 210, 211, 213, 214). However, the analysis also showed that the post-test or the follow up was not completed in all these studies. Moreover, in several studies, differences and characteristics of participants in pre and post-test were not adequately presented, and the analysis of loss was not (172, 210, 211, 214). In some studies, statistical analysis was not adequately reported, so it was unclear whether appropriate statistical tests were used (208, 209).

According to the Critical Appraisal Tool checklist, the two randomized trials included in the analysis had a high methodological quality in categories related to randomization and employment of appropriate statistical tests (182, 212). However, the main issue with the randomized controlled trials was that it was impossible to conclude on methodological quality in categories related to the allocation of intervention and participants' bias. This was because studies do not clarify whether the allocation was concealed, which is important for these types of studies, and whether participants were blinded, which is another important factor for minimizing the risks that may bias the research. Moreover, in the study by Bruton et al., it was not clear whether research assessors were blinded and as well as in another study by Martinson et al. 2017, it was not clearly stated whether participants were similar at the baseline (182, 212).

Regarding the qualitative study by Seiler et al., the analysis showed that almost all categories of the Critical Appraisal Tool checklist were adequately reported, indicating a high methodological quality of the study (215). Only one item was not reported and that is the one related to the potential influence of researchers who conducted the study on research and vice-versa. The details of the critical appraisal of evidence analysis are presented in **Appendix 10**.

4.4. Qualitative study on the development and implementation of research integrity documents and practices in biomedicine and other disciplinary fields

Based on the thematic analysis described in the methods, this qualitative study yielded results regarding RI and RI guidance documents development and implementation presented in **Figure 6**.

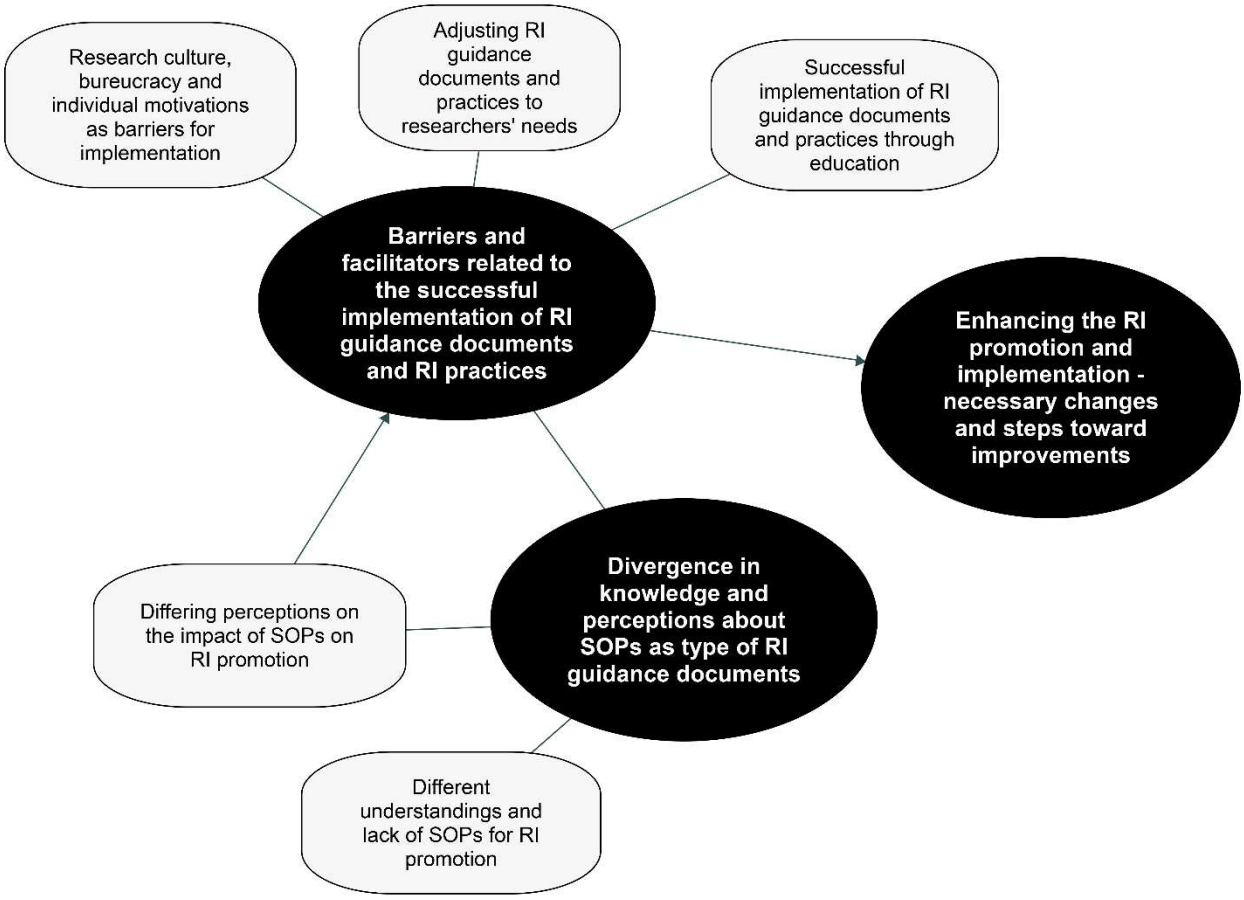

Figure 5. Thematic map of themes and sub-themes. SOPs – standard operating procedures

4.4.1. Theme 1: Divergence in knowledge and perceptions about SOPs as type of RI guidance documents

This theme deals with the study participants' knowledge and perceptions on RI guidance documents, emphasizing the SOPs for RI promotion. The theme refers to the participants' different understanding of SOPs for RI as RI guidance documents and different perceptions on

their applicability and impact on RI promotion. Two sub-themes were developed as a part of this main theme – "Different understandings and lack of SOPs for RI promotion" and "Differing perceptions on the impact of SOPs on RI promotion" are developed as a part of this theme.

Different understanding and lack of SOPs for RI promotion

Most participants were not familiarized with the SOPs in the context of RI. While some participants had some experience and were familiarized with the step-by-step procedures that describe certain research processes and the roles of those involved in that research, most of the participants did not distinguish well between the detailed or general guidance documents related to RI. Further, when asked about SOPs for RI the participants referred to various RI guidance documents that are well-established in his field and perceived as gold standards. These included, for example, the European Code of Conduct for RI (37) or reporting guidelines, such as those available by Equator Network (216). The reasoning behind why reporting guidelines were mentioned in the context of SOPs could be because they contain step-by-step instructions on how to adequately and thoroughly report research. Another example of SOP was guidelines for submitting images to journals. However, several participants mentioned they are familiar with SOPs in general, as they are used, for example, in collecting samples for research, but these participants were also not familiar with currently existing SOPs for RI, but that rather the guidance for RI tends to be more general and aspirational. Citations supporting the findings for this sub-topic are presented in **Appendix 11**.

Differing perceptions on the impact of SOPs on RI promotion

Most participants agreed that SOPs could be a valuable addition to existing RI tools, e.g., codes, guidelines, and checklists. However, not all participants were completely positive about this. While some participants saw potential in SOPs to help researchers easily follow their research tasks, detect and resolve RI issues, and avoid sloppy science, others were quite skeptical that the development of SOPs for many existing research organizations that operate in different environments and disciplines would be feasible. One participant emphasized that SOPs would not be able to influence researchers' behavior as RI entails more than merely following procedures (this participant sees RI as a state of mind – whether you do research properly and honestly or not). Further, some participants thought that the development of SOPS in some disciplines would not be an issue, as well as for research organizations, but on the other hand

they considered the development would be problematic for funders and in areas where there is less technical and procedural work and more freedom of creation and pursuit for innovation. Citations supporting the findings for this sub-topic are presented in **Appendix 11**.

4.4.2. Theme 2: Barriers and facilitators related to the successful implementation of RI guidance documents and practices

The process of translating and applying written RI guidance in real-life research situations was seen by participants as vital for fostering RI and avoiding research misconduct and detrimental research practices. Research organizations can have millions of procedures, policies, and SOPs for RI but if these are not implemented properly there is a high chance that RI will not be fostered in practice as researchers will simply not know how to properly use the written guidance. This second theme focuses on various factors that positively or negatively influence the implementation of RI guidance documents. The theme captures the factors related to the existing system of science and researchers-related factors and their interrelatedness. Three sub-themes were developed – "Research culture, bureaucracy, and individual motivations as barriers for implementation", "Adjusting RI guidance documents and practices to researchers' needs" and "Successful implementation of R guidance documents and practices through education".

Research culture, bureaucracy, and individual motivations as barriers for implementation

Several factors related to the research culture and researchers operating in the existing research cultures were mentioned in the context of factors that may negatively impact the implementation of RI and RI guidance documents. Lack of consistency and harmonization was often mentioned. This means there are major differences between the academic systems and cultures in different countries and between disciplines, and these are perceived as an issue for RI that requires some level of uniformity in application of RI standards. Participants considered RI as a global endeavor that aims for uniform application of fundamental principles and norms. Because of the prominent differences, RI guidance documents often contain various definitions o9n for example detrimental research practices that could be uniformed and universally applicable since for example violating authorship standards or who deserves the authorship could be defined equally regardless of the disciplinary field. This issue further leads to differences in how RI guidance documents are applied and interpreted in different settings,

making it difficult for researchers to figure out what rules to comply with. This is especially pronounced in international collaborative projects or when researchers move from one place of work to another.

Participants also mentioned other issues that are related to pressures and competitive research culture which have a huge impact on RI promotion and implementation. Pressure to publish in high-impact factor journals, to publish a lot of research to advance in career, or to obtain funding are seen as factors that stimulate poor research behavior and encourage a research culture in which RI is not an imperative. In addition to these external factors, the participants also mentioned factors related to individual researchers: internal motivations pertaining to career advancement, financial gain, success, and awards, which are often the reason why researchers do not adhere to RI guidance documents and practices.

However, participants saw researchers' behavior and motivations as a product of current research culture which indicates that fostering RI and implementing RI guidance documents should be an all-encompassing process that includes efforts on different levels. In addition, another important element was mentioned – researchers' perception of RI guidance documents. Researchers often have negative perceptions of RI guidance documents and see them as irrelevant for their research, a formality, or administrative burden that slows down their research work and diminishes creativity. Further efforts to develop and implement RI guidance documents should also consider this factor, and try to create guidance documents that will be useful and practical in real-life research settings. Citations supporting the findings for this sub-topic are presented in **Appendix 11**.

Adjusting RI guidance documents and practices to researchers' needs

One of the major points of discussion was related to factors that can facilitate the implementation of RI guidance documents, and that are closely related to previously mentioned challenges – research culture, harmonization and bureaucratic challenges, and individual motivations for using RI guidance documents. These factors are seen as possible solutions for eliminating the barriers for implementation of RI and RI guidance documents. Participants emphasized researchers' needs related to the discipline they are working in, as well as specifics of different disciplines and research methodologies as important to be taken into account already in the phase of developing RI guidance documents. By doing so, newly created RI guidance documents will be perceived more relevant by researchers. Tailoring RI guidance documents to

researchers' needs is seen as an important prerequisite for successful implementation of RI guidance documents among individual researchers.

Successful implementation of RI guidance documents and practices through education

RI education was often mentioned by participants and in the context of its importance for successful implementation of RI and RI guidance documents. RI education was perceived as an active approach to implementing RI, which contributes to awareness raising and obtaining new knowledge on RI issues and existing RI guidance. Moreover, RI education was seen as a helpful tool for helping researchers learn where to find and how to use available RI guidance and tools in everyday work. However, in order for RI education to be effective, participants thought that RI education should be properly planned, carefully structured and targeted. The need for continuous education was emphasized for researchers of all career stages, especially for mentors and supervisors for whom educational courses in RI often lack. Same as tailoring RI guidance documents to researchers' needs, participants mentioned the importance of tailoring RI education to researchers' needs as well. In this context, the participants mentioned that having basics and more general RI courses is a good start for getting familiar with RI concepts and when you first enter research world, however as researchers advance in their careers and specialize in certain fields, or become mentors and supervisors, RI education should be tailored to serve these specific needs. Adequate approach to RI educational courses was also mentioned by participants. The participants emphasized the benefits of using real-life examples and more interactive courses. as well as examples of RI cases to help researchers better understand RI concepts and issues that may arise during the research, as well as how to avoid them or if they happen, how to resolve them. Unfortunately, participants mentioned that many courses existing today lack active engagement and researchers' reflections, and more often are simple, one-time lectures or assignments in which researchers are not engaged enough, but rather do it because they have to since it is another administrative obligation. Citations supporting the findings for this sub-topic are presented in **Appendix 11**.

4.4.3. Enhancing the RI promotion and implementation – necessary changes and steps toward improvements

The third major theme focuses on improvements in the approaches to RI. This team captures participants' numerous examples on how RI could be improved in future, together with

RI guidance documents. In general, the participants agreed that having step by step RI guidance documents would be beneficial for fostering RI. However, the participants emphasized the importance of having general guidance documents as well. The general guidance documents are seen as important because they create a basis consisting of most important RI standards and principles that can be further tailored and developed into more specific guidance depending on disciplines and research needs. Thus, the participants suggested that the best option in the case of RI guidance documents would be to have a combination of general, aspirational RI guidance documents and more detailed ones, as they complement one another.

Further, some participants gave examples of RI-related issues they would like to see in guidance more often, as currently there is not adequate guidance on these issues. Moreover, the participants mentioned they would like to see guidance for these issues to be more detailed and for example in the format of SOPs. These include guidance for submitting research grant proposals and SOPs for funders on how to assess grant applications. However, the same participants were also worried whether SOPs for funders would be a possibility and mentioned that funders usually have guidelines and recommendations that are not very detailed. When it comes to the development of new guidance documents, the participants emphasized the involvement of researchers in this process from start to finish. As researchers need to perceive RI guidance documents relevant for their work in order to adhere to this guidance, it is important to take their thoughts and proposals into consideration in the process of development of RI guidance documents (which is currently not always the case). In addition, the participants also mentioned the importance of more financial and resource support for research organizations that create and implement new guidance documents, policies, and procedures for RI. Further, the participants mentioned other initiatives that research organizations could introduce to incentivize implementation of RI and RI guidance documents within their structures. These mostly referred to incentives related to evaluation of researchers, that should be shifted from taking into account quantitative instead of qualitative indicators. RI bodies were also often mentioned by the participants as important for successful development and implementation of RI guidance documents. RI bodies should exist in each research organization to oversee and handle RI issues, as well as to provide support for researchers. The participants mentioned that many organizations already have these bodies, however these organizations should also work

on developing guidance for these bodies on how to work, and this guidance could be in the format of SOPs.

The role of funding organizations and journals and publishers was also discussed by participants. In the participants' opinion the influence of funders on RI promotion and implementation is very important since funders provide money for research and they have the power to impose RI requirements. The participants suggested how funders can support RI, and that is by developing their own RI guidance documents and imposing RI requirements for research organizations and researchers. As for the role of journals and publishers who publish scientific work, the participants most often mentioned the importance of the initiatives, such as retracting articles based on fraudulent research. Further, the participants commented that these stakeholders do not take enough responsibility for RI today, and that they should take more responsibility for RI and be more transparent in how they handle retractions, especially in regard to clear identification of retracted articles, as well as access to information on corrections to the published record. Citations supporting the findings for this theme are presented in **Appendix 11**.

5. The biomedical perspective

This section provides the main results from the scoping reviews, and qualitative interviews study explicitly related to biomedical research. The following is based on the separate analysis conducted on scoping review data related to biomedicine and on data of stakeholders working in the biomedical field in qualitative interviews.

When we talk about RI guidance documents, besides the prevalence of guidance documents written in general for RI, the second most prevalent were guidance documents for biomedical research. The investigation of the existing RI guidance documents in biomedicine showed that most documents were guidelines and related to individual researchers. The guidelines, however, varied in their structure. So, while some guidelines were very much detailed, outlining specific procedures about RI and aiming to guide researchers to the course of a particular action, other guidelines were extensive and related to the main elements of RI. This includes the basic definitions and principles and very general aspirational norms aimed at RI promotion. Although Ri guidance documents exist in biomedicine, based on the scoping review study included in this thesis, there still needs to be more guidance, even in biomedicine, for institutional efforts in promoting, implementing, and fostering RI. Further, biomedical RI guidance documents showed a need for more focus on research funders and other structures or bodies relevant to RI, such as RI officers or advisors. Regarding the phases of the research process, most of the biomedical RI guidance documents were focused on the conduct of research, i.e., procedures on avoiding, for example, falsification, fabrication, and plagiarism and ensuring the robustness of the methodologies and performed research processes. As for the topics related to RI, most of the identified RI guidance documents from biomedicine emphasized topics such as ethics in research (research with human and animal participants), conflict of interest (financial and personal), study design, and research protocols, as well as data protection in mostly new documents. Only one SOP was identified in the full scoping review, and it was related to biomedical research, more precisely, procedures for investigating research misconduct. Although, as presented in the introduction of this study, SOPs are not unusual in biomedical research, it is a novel guidance document regarding RI in this field.

As for the factors influencing the promotion of RI and RI guidance documents, the literature related to biomedical research showed that the most prominent factors that impact RI promotion and implementation are related to individual researchers, followed by organizational

influences and structures. Personality traits and influences of role modeling of mentors and supervisors were studied among biomedical researchers intensively and showed that both could have negative or positive impacts on researchers' behavior. For example, junior researchers learn specific laboratory procedures from their mentors and supervisors in the research laboratory. How they will adhere to RI standards in future research depends significantly on the behavior of those who supervise and educate them. Further, having some degree of RI education was mentioned across biomedical literature as a factor that positively influences researchers' behavior. RI education is also related to organizational influences. The role of organizations in organizing proper research integrity and ethics education was recognized as an important factor in promoting RI in biomedicine. Many factors related to research organizations, mentioned across biomedical literature, were related to conflict of interest. More precisely, institutional efforts in suppressing potential conflicts of interest were recognized as an important aspect of promoting RI. Regarding the system of science, the factors promoting or hindering RI are mostly common for all disciplines. However, there is still a prevalence of publication pressure and competition in biomedical research, whether it is because of the strong incentives (e.g., gaining recognition for important medical discovery and success or large amounts of funds invested in biomedical research), or just because of the fast-paced and competitive environment.

The interviews with biomedical researchers showed that although RI guidance documents exist in a large number in biomedicine, the implementation processes may be suboptimal due to the lack of involvement of researchers in the mere process of development of guidance documents, as well as due to the lack of RI education that will be engaging enough and useful for biomedical researchers rather than general and vague. It is interesting that although SOPs were not in the scoping review identified in a large number, interviewers from the biomedical area thought of them as very useful and practical for biomedical research as often the existing guidance is not precise enough and leaves a lot to the interpretation of researchers and organizations, subsequently leaving more space for mistakes and misconduct.

6. DISCUSSION

The findings from the studies described in this doctoral thesis highlight important challenges related to developing and implementing RI and RI guidance documents. National structures for RI often differ between countries as each country has its legal framework and context. However, the disparity at the national level leads to even more differences between research organizations. Existing RI guidance documents are numerous for researchers in biomedical sciences, however, researchers do not always adhere to these due to the lack of guidance documents optimality for practice, as well as systemic factors that often dictate what research will be valued or rewarded and how. Prominent differences exist in the number of guidance documents between biomedicine and other scientific fields. Other disciplines seem to be lagging behind biomedical guidance documents, which can often create confusion in collaborative interdisciplinary projects. SOPs seem to be valued by biomedical researchers, although they are still not a usual RI guidance in any field. Together with broader and general guidance, research organizations and other policymakers should invest efforts in creating SOPs or similar detailed guidance for RI in biomedicine. With demanding schedules and administrative tasks, researchers want guidance that will clearly state what should be done and what are the steps of a certain action, instead of dealing with vague guidance documents that are subject to different interpretations.

6.1. Study on research integrity structures and processes in Europe

The analysis of existing RI frameworks in 16 European countries outlined the variety of approaches to RI promotion and implementation. The analysis showed that some countries are front-runners when it comes to RI, with well-established RI policies, practices, and structures. On the other hand, the analysis also pointed to the fact that some countries are just starting their journey in RI, and that the concept of RE is often used as a synonym for RI. Although most of the analyzed countries are a part of the European Union, where a certain level of uniformity regarding RI could be expected, the analysis showed a diversity in existing RI frameworks, as well as the level of development of RI and RE structures. Nevertheless, RI and RE are continually developing and getting more attention within the research community, which is evident from comparison of previously conducted analyses and this study (32, 33, 217).

As shown in the general mapping of research frameworks in this study, and by the comparison of the statistics through the years, the number of people being employed in the public and private research sectors is on the rise. Further, more research funds are being invested in research every year, although there are big differences between countries. Which can also indicate that countries will invest different amounts of resources for RI and that is one of the reasons why we have big differences between countries, regarding RI policies and structures and their implementability. However, this study showed that 15 out of 16 countries have at least some sort of national establishment for RI. This means that the awareness of the importance of RI and recognition of its specifics compared to RE is also on the raise. The term "a sort of establishment" is deliberately used because the way the RI structures are organized is not the same between the countries. Some countries are more developed in this area and have the umbrella RI bodies on the national level that handle RI issues and support research organizations, in other countries, there are only bodies at research organizations, e.g., universities that are designated to handle RI issues. Having the latter could also be prone to more discrepancies between how RI is handled, especially if we think about how cases of research misconduct and other detrimental research practices are handled. In that sense, having RI bodies at the national level is something that countries should strive for to ensure a certain level of equal implementation of RI standards in practice. Unfortunately, and evident from the study analysis, the increase in RI awareness is paralleled by a small percentage of countries in which RE bodies, such as RE committees handle RI issues, although it is well accepted practice today that RI and RE are similar but different concepts, with different aims and stakeholders involved. This has not changed since the previous analysis conducted under the MLE for RI in 2019 (32, 33), but it is however something that needs to be changed in future. The distinction between RI and RE is necessary to handle both ethics and integrity issues (2).

Regarding the RI guidance on the national level, the analysis showed that some countries have codes or guidelines at the national level. However, development of RI guidance documents is today emphasized more as the responsibility of research organizations. This is in accordance with the scoping review of RI guidance documents that is included in the thesis and which showed there are a great number of various guidance documents for RI promotion developed by research organizations. However, there are also significant differences in the content of these guidance documents, which warrants the conclusion that more harmonization is needed in this

aspect (100). Similarly, the study exploring the codes of conduct for RI across Europe showed divergences and differences in practices and standards presented in the codes (83). There are also initiatives aiming at harmonization. For example, the European Code of Conduct for RI was developed as the framework for regulating RI in Europe. The national guidance documents in Europe could in the future be developed based on the European Code of Conduct for RI principles, and built upon its recommendations. This could potentially ensure a certain level of uniformity and contribute to equal application of RI standards and hence better avoidance of research misconduct and other detrimental research practices. The study on RI frameworks also showed that only a small number of European countries have established legal protection for whistleblowers, although it has been emphasized across literature that whistleblowers have an important role in preventing future misconduct cases (3, 37, 88). The lack of proper whistleblowers' protection is also found to be one of the negative factors that contributes to research misconduct in the scoping review on factors influencing RI implementation. Having laws and procedures in place for the protection of those who witnessed research misconduct and decide to report it could help in encouraging people to report research malpractice without fear of the negative consequences to which whistleblowers are usually exposed.

Regarding the national laws and regulations concerning RI, the study analysis showed that all countries have at least one law concerning different aspects of RI and RE. The number of specific laws or bylaws ranged from 2 (Croatia) to 17 (the Netherlands). The area of data protection is mostly well established and regulated by national laws. This is probably due to the GDPR which is mandatory in almost all countries included in the analysis, as they are EU member states. However, since the GDPR explicitly says that data protection should be more precisely defined by the member states laws, which also includes data protection in research, not all countries included in the analysis have such national laws or at least not developed enough (Croatia is an example) (218). Another example of policies that are applicable across countries is related to the European Commission funding program Horizon Europe. Horizon Europe in 2021 implemented the requirement that all grant applicants have to declare compliance with RI standards and practices outlined in the European Code of Conduct for RI (51). This made the code a "soft law" implemented across European countries.

Analyzing the measures aimed to promote good scientific practices and open science put focus on RI training and open science initiatives. RI training is considered to be one of the

initiators of RI implementation (219, 220). The analysis conducted in this study showed that there is a great diversity between obligatory and non-obligatory nature of the RI training which did not exist only between countries , but also within the countries. The analysis showed that RI training is mostly non-obligatory in many countries included in the analysis and that the most targeted population are PhD students. Although RI education and training are important for PhD students, recent studies, including the scoping review on factors influencing RI implementation showed that more initiatives are needed for educating senior researchers as well, since the senior researchers are usually supervisors and mentors and early-career researchers often look upon their research behavior (128, 219). Empowering researchers of all career stages to engage in RI training and translate the acquired knowledge to future generations of researchers is recognized as being an important aspect of future initiatives in the RI field. Regarding open science, within the analyzed countries publishing research in open access format and opening research data was most addressed across analyzed policies. The analysis showed that open science is well addressed across countries and their policies as most countries have national strategies for open science, as well as well-established structures to ensure open access to publications and research data, for example through repositories.

Recommendations for future RI initiatives

Based on the country report cards study, several recommendations can be made to foster RI in future. First, although RI is getting more cognition across European countries as a concept different from RE, some countries still need to work on separating the policies and guidance documents, as well as practices for RI and RE. Having separate structures is important for adequate promotion and implementation of RI. Second, although many organizations have various bodies for handling RI issues, a RI body at the national level that will support research organizations' RI bodies is important for harmonizing approaches to RI between countries and within the same country. Finally, having nationally applicable guidance documents for RI can help in harmonization and uniformity when dealing with research misconduct and detrimental research practices. It can also possibly help researchers avoid confusion when it comes to applicability of rules when changing the place of work within the country.

Study strengths and limitations

Although national RI structures are important for promoting and implementing RI and creating a basis upon which organizational guidance can be built, this study did not take into account organizational differences that exist within a country. Hence this study is limited to providing a very broad and general overview of RI structures as exploring the organizational nuances was not in the scope of this study. However, as previously mentioned, having a general and broad overview or RI status quo across European countries provides a basis for organizational RI development and a glimpse into what we can expect at the organizational level. If there are strong RI incentives at the national level, we can most certainly expect that organizations in these countries will put a strong emphasis on RI, and thus invest more resources into development of optimal RI guidance. Another possible limitation could be that the study took into account only publicly available information, hence there is a possibility that the study results do not include all possible aspects of research and RI. This means that information on publicly available organizational policies was not included. Nevertheless, the study captured enough information for providing a broad overview of how RI is established, promoted, and implemented across countries and thus providing input into what we can expect at the organizational level.

Conclusions

The country report cards study showed the existence of many initiatives aiming at promoting and implementing RI across different European countries. Unfortunately, the analysis also showed that even 30 years after the RI field was established there are still prominent differences between countries in how RI is handled. This points to the need for continuous efforts by European countries in the RI development that will in the future reach at least a certain level of harmonization when it comes to how RI is dealt with. RI country report cards have an element of continual learning exercise, designed for exchanging knowledge and experiences with RI. Further, country report cards can be used as a motivation and inspiration to those who work on the promotion and implementation of RI. Examples and best practices from countries who are front runners in this area, can help those countries who are still at the beginning of their journey with RI, like for example Croatia.

6.2. Study on the existing research integrity documents available in biomedicine and other disciplines

The scoping review on the existing RI documents identified a number of available guidance documents for the improvement of RI. Most of the identified guidance documents were related to research performing organizations, and were in the form of guidelines. Most of the identified guidance documents addressed RI topics related to the category of analysis "RI violations and resolutions", as well as "RI promotion". Only a small number of RI guidance documents was related to research funding organizations which shows the difference regarding RI in the context of different types of organizations. The majority of identified guidance documents were not related to any specific discipline, but were rather related to research in general. The scoping review showed that a substantial amount of RI guidance documents were developed for biomedical research, while there is a small number of disciplinary tailored guidance for RI in natural sciences, social sciences, and humanities.

While most guidance documents were developed for and related to research performing organizations, some of these documents briefly mentioned funders as important stakeholders in the research process. However, there were only a few guidance documents developed solely for funding organizations which pointed to a prominent gap in knowledge. In the context of RI, this could be an issue since research funders play an important role in influencing how research is conducted by research organizations and individual researchers (3). Although researchers build their careers in research organizations and their behavior is often influenced by organizational climate and policies, research funding organizations can impose additional safeguards if research organizations fail to do so. Moreover, measures imposed by funders can also be aimed at research performing organizations, for example when setting out calls for funding or selecting and monitoring funded projects, which often can dictate organizational ethical climate and which policies will research organizations implement within their structures. Hence, by demanding the establishment of RI policies and practices from research performing organizations, funding organizations can also indirectly influence researchers' behavior (221). Some of the important requests that funders can impose to research performing organizations could be a request for implementation of clear guidance documents and practices for handling research misconduct or request for compliance with the principles of open science and transparency in research publications (222).The analysis of stakeholders to whom the RI

guidance documents were aimed, showed that although a large number of documents addressed research performing organizations (organizational directors, managers and boards), most practices addressed individual researchers. Only a small number of RI guidance was addressing RI structures, such as RI offices, committees, or advisors. This could be because many organizations still do not have specific bodies appointed to deal with RI issues, which is also confirmed by the analysis of RI frameworks (32, 127). Additionally, research processes and RI topics analysis showed that efforts to establish RI bodies are emphasized as an important role of organizational management in research organizations, and by policymakers.

Most guidance documents included in the analysis originated from the USA, which can also be due to the methodology used in the scoping review, since the search sources were also the United States Office of Research Integrity website and the publication by the United States National Academies of Sciences, Engineering, and Medicine. Also, the search strategy was limited to English, which can be another reason why the guidance documents from English language countries were prevalent. Nevertheless, the analysis also showed the strong RI efforts internationally as many guidance documents were not related to any specific countries. These guidance documents were mostly developed as efforts of collaborative projects and international organizations focused on RI. To conclude on the usage of these guidance documents, it would be necessary to explore which guidance documents were implemented across research organizations in different countries. However this should exclude the international legislative documents, for example those of the European Union which are mandatory in member states.

The analysis showed that guidelines were the most common type of RI guidance documents. However, there was considerable variability in the RI topics and the level of elaboration of RI guidance presented in different guidelines. While some guidelines were focused on a single RI issue or specific stakeholder, and describes the specific procedures in detail, for example on data management (223) or how to respond to misconduct in research (224), other guidance documents presented different RI aspects in a more general manner with the addition of specific recommendations for various stakeholders (3, 164). Only one of the guidance documents in this study was in the form of SOPs (n=1). Research performing and funding organizations probably have SOPs for different administrative procedures or for example for conducting research in a laboratory, however this scoping review was focused on SOPs for RI which evidently are rare. The reason could be that research performing and funding

organizations do not have their SOPs publicly published. However, having RI guidance in the form of SOPs could be helpful, especially in the context of discipline differences where general RI guidance may cause confusion on its applicability in different research fields. SOPs could be developed also for more general actions, like for example for uploading research results to a repository or the registration of research protocol. The same could be applicable for RI bodies when it comes to handling the cases of misconduct to ensure that the same procedure, from investigation to sanctioning, was followed in each case (154).

The analysis of processes and RI topics for research performing and funding organizations brought up several RI issues that were emphasized across guidance documents as responsibilities of those at the organizational level, i.e., policymakers. Most of these guidance documents were related to the process of “RI violations and resolutions" and “RI promotion”. For the topic “RI violations and resolutions” guidance documents were mostly focused on processes related to investigations of research misconduct and how the cases of misconduct were handled, as well as the importance of having clear definitions of what constitutes research misconduct and detrimental research behavior. For the “RI promotion” most guidance documents were focused on the development of RI guidance documents as tools for promoting RI, as well as on the establishment of RI bodies. Having RI training and education, as well as the development of adequate infrastructure for supporting research data management was also mentioned across guidance documents as the responsibility of research organizations. These roles reflect the important role of research organizations in creating the environment in which researchers will be motivated to follow RI standards in their work (54, 74, 154).

The analysis of guiding principles, conducted in the scoping review showed that naming of RI principles differs between guidance documents, but the meaning of the RI principles was mostly the same. The European Code of Conduct for RI emphasizes for example, the principle of ‘reliability’. Reliability is in the code defined as employing a research methodology that will help enhance the quality of research, and ensure the trustworthiness of one’s work (37). In a publication by NASEM, the same guidance pointing out the validity of research was described under the principle of ‘accountability’ (3). Moreover, ‘accountability’ is also used here to demonstrate researchers’ responsibility toward research organizations and society (3) which corresponds to the principle of ‘accountability’ in the European Code of Conduct for RI. The principles of ‘honesty’ in the European Code of Conduct for RI, is defined as being honest and

fair in research, valuing transparency in reporting research, as well as having an unbiased approach to the research tasks (37). In publication by NASEM two other principles besides honesty are defined – 'objectivity' and 'openness' – focused on avoiding biases in research and reporting accurately to the research community. The principle of 'respect' by the European Code of Conduct for RI is directed toward different stakeholders, starting from other researchers and collaborators to the research participants and society. On the other hand, NASEM publication describes respect toward others in the research process by using the terms 'stewardship' and 'fairness'. The definitions of the principle of 'respect' were the most diverse regarding the terms used. The analysis of principles showed a great variety of principles that should be taken into account when considering RI guidance. These fundamental principles create a foundation upon which more detailed guidance is developed. General guidance may not be enough, especially in the context of scientific disciplines which would benefit from more tailored RI guidance, however this general guidance is a starting point to any other more detailed guidance and presents the core of values every researcher should respect in their research work.

Study strengths and limitations

The main strength of this study would be its comprehensive nature. An extensive literature search that included both peer-reviewed and grey literature publications from various sources, and that was conducted by employing a robust methodology is a strong point of this study that enabled valuable results. The comprehensive search allowed the creation of a library of publications related to RI guidance documents addressing different stakeholders in different scientific disciplines. Most importantly, the scoping review enabled identifying gaps in knowledge and thus created opportunity for further development of RI guidance documents. There are also several limitations related to this study. Some important documents could be missed due to the human factor in the analysis of titles and abstracts, because information provided therein was not sufficient for the inclusion in the analysis. Further, it was not feasible to perform the search of every guidance document that exists across many research organizations. Expanding the search to the various websites of research performing and funding organizations where we might have found additional documents raises a question for the feasibility of the study. The same goes to expanding the grey literature search to publications in languages other than English. Furthermore, the accessibility of RI guidance documents may be low, as shown also in some other studies (30). This means that even if the search of individual

organizational websites was performed, there is still a doubt that it would provide a comprehensive insight into the totality of RI guidance documents. Five documents were unable to be retrieved, but since they dated from the 90s the guidance presented in them is most probably obsolete and was captured in more contemporary documents included in the analysis.

Conclusions

The scoping review showed the existence of numerous RI guidance documents intended for various stakeholders and RI topics. However, the scoping review showed the prominent gap in knowledge when it comes to the RI guidance documents made from and for research funding organizations. Although funders play a major role in fostering RI, their efforts in the development of RI guidance are still to be brought up. Moreover, besides differences between types of organizations, the analysis in this scoping review showed prominent differences between scientific disciplines well. The majority of the body of literature included in this study consisted of the documents from biomedical research, while there was a significant lack of documents in humanities. It seems that RI efforts are not equally distributed across scientific disciplines, but taking into account that misconduct can happen in every research (although it may be different in biomedicine than in humanities) it is very important that other disciplines step up and invest more efforts in RI. Every research is important as it helps in the development of future knowledge, hence in every research it is important that it is conducted appropriately, with integrity and in accordance with high professional standards. This study also identified that RI guidance may come in different forms, from more general to very detailed ones. Although SOPs were barely identified in this study, with their detailed approach to RI issues they can be seen as an extensive hand of more general and well accepted guidance like for example codes of conduct.

6.3. Study on the individual, organizational, and systemic factors influencing the implementation of research integrity in biomedicine and other disciplines

This scoping review identified various factors that may positively or negatively impact RI promotion and implementation. Most of the publications included in the analysis were related to biomedicine or research in general (not related to specific disciplinary fields) and addressed various factors related to all three levels – individual researchers, organizations, and the system of science. Although many publications addressed factors with the positive impact, there was a prevalence of identified factors with the negative impact on RI promotion and implementation. Further, the analysis of RI interventions showed that RI education may be helpful for encouraging adherence to RI standards, however some formats of Ri education were considered better than others in achieving this. Nevertheless, the results 9of the scoping review showed there are difficulties in assessing the effectiveness of RI interventions due to the issues related to the methodological quality of studies included in the analysis. In the further sections, the focus is on the areas and factors often mentioned across analyzed publications in the context of what hinders RI promotion and implementation, as well as on efforts and improvements needed for improvements and strengthening RI.

Analyzed studies that assessed RI interventions showed that RI education is an important factor in promoting and implementing RI among individual researchers. However, the findings from these studies suggest that available RI education might be suboptimal in delivering the full benefits of RI training, and that modifications in the content and delivery of training are needed. Several recommendations and implications for practice can be made based on the findings from the analyzed studies. First, modern or novel approaches to RI education, such as sensemaking or role-play scenarios seem to have more impact on RI promotion as they manage to engage researchers more in the training, compared to usual theoretical lectures. Hence, RI initiatives focused on education should consider introducing more interactive, active, and engaging activities that can consist of role-play scenarios, real life cases and examples, and metacognitive reasoning strategies. Recent research on this topic showed that many RI educational resources and training exist but they are still focused more on passive rather than on pro(active) participants' participation (225). Second, analyzed studies suggested that upon developing a training, creators should think carefully about the fact that one size does not fit all. RI training should be tailored to the needs of trainees, considering their research background and discipline

they are coming from. This can positively influence researchers' perceptions of RI training and help in internalizing the RI knowledge. A tailored to the needs approach was also proposed by other studies (105, 219, 220) which points out that the research community is in the need of tailored RI education. Furthermore, regarding internalizing RI education, a virtue-based approach to RI education was explored. Emphasizing researcher's character, virtues, and values may contribute to greater adherence to RI standards and norms (226). Finally, studies included in this scoping review analysis proposed that short-term education may not be effective enough in ensuring the long-term effects of RI training. Hence, RI education should ideally be held over a certain period of time or at different points of the researcher's career. Unfortunately, considering the results of the critical appraisal of evidence included in this study, and that showed methodological issues in studies that tested RI interventions, it is not possible to completely conclude on the effectiveness of the proposed RI education initiatives. Future research, for example a systematic review assessing the effectiveness of all available RI educational programs could contribute to creating the optimal RI education program that will deliver most success in terms of its effectiveness.

The studies included in this scoping review often mentioned the importance of having in place different guidance documents for RI, which is in accordance with other studies on which thesis is based (100, 105), as well as some other newer studies (73). However, the studies included in this scoping review also emphasized that mere existence of RI guidance documents does not guarantee their effectiveness in improving the adherence to RI standards in practice. The lack of effectiveness is often mentioned in the context of existing pitfalls in the guidance documents' implementation process. For example, a study by Mabou Tagne et al. which explored researchers' perceptions of the institutional policies and guidance for reducing research misconduct, found that researchers perceived the existing policies and guidance as highly effective but that there is a low possibility that those who committed research misconduct will be caught and sanctioned (211). This again may indicate that the process of implementation of RI policies and guidance documents, as well as proper procedures that are based on the written guidance are suboptimal. Further, some studies emphasized researchers' awareness of the existing RI guidance documents, which seems to be low as well. This could also be because proper implementation, awareness-raising, and educational activities were not conducted (227, 228). Some studies included in the scoping review dealt with the content of RI guidance

documents and showed the existence of inconsistencies in definitions, as well as the lack of practical support and guidance on how to properly handle RI issues. The inconsistencies and lack of support further contribute to the lack of understanding the RI guidance, susceptibility to multiple interpretations, and misinterpretation of RI guidance in practice (30, 119, 178, 201, 229). For better implementation of RI guidance documents and practices, research organizations as well as other stakeholders involved in the process of developing the guidance, should take into account ideas and suggestions of researchers, as well as including researchers more in the development process (105). This could include having open discussions with researchers through forums or conferences, on the needs and requirements of different disciplines, research, and academic systems for making guidance documents more optimal and applicable in every-day research.

The implementation of RI guidance documents may be more pronounced in disciplines that have an adequate number of guidance documents, however in some disciplines the mere existence of RI guidance is still an issue. While the first scoping review showed the lack of RI guidance documents in natural sciences and humanities (100), the analysis conducted in this scoping review also yielded a small number of studies referring to explicitly natural sciences and humanities. Since this scoping review was focused on factors influencing RI promotion and implementation, these results point out to the gap in knowledge when it comes to explaining what all influences RI promotion and implementation in these disciplines. Regarding the disciplines, this scoping review also pointed out differences in RI topics that were addressed and emphasized across studies from different disciplines. Issues related to conflict of interest, research independence, and relationships with industry were often mentioned across studies related to biomedicine, but were not so common in other disciplines. Biomedical research receives a huge amount of money for new medical products and solutions that will help humans live longer and healthier, and it is perhaps commercialized more than research in other disciplines. In this scoping review, studies from natural sciences and humanities mostly addressed RI issues related to evaluation criteria, pressure to publish, plagiarism in research, and lack of sanctions for research misconduct. Some other studies also reported on differences in how RI topics are prioritized across disciplines. A study by Haven et al. showed that researchers from biomedicine and social sciences prioritize sloppy science and supervision issues, while researchers from natural sciences are more focused on the issues related to

plagiarism and stealing of publication ideas (108). Another study by Haven et al. showed that researchers from biomedical and natural sciences have more positive perception of RI compared to researchers working in humanities and social sciences where there is a lack of emphasis on regulatory RI bodies (which often do not exist) (118). On the other hand, biomedical researchers have been aware of the regulatory bodies and committees that exist for a long time and have an important role in evaluating and approving research. Based on this, we can conclude that not all RI topics are equally important across research disciplines, and when creating RI guidance documents the priority should be given to topics that are considered as important and relevant to researchers from certain disciplines. However, within each discipline, the same priority should be given and efforts should be made in order to harmonize the guidance and standards that researchers should follow.

Another, often mentioned across publications, factor that may hinder the implementation of RI is related to the existence of RI structures and bodies that will deal with RI issues and cases of research misconduct. It was already mentioned in the country report cards study that many countries lack these bodies at the national level, however the situation is also not ideal in research organizations which also often lack designated RI bodies. Moreover, in many research organizations (partially also due to the national inconsistencies) there is no clear distinction between RE and RI (2, 21, 32). As previously mentioned, while RE is a more generic concept, focused on addressing the application of ethical principles and values related to research, RI is focused on adherence to professional standards and responsibilities set up by research organizations and research community (2, 32, 33). The distinction between these two imposes distinct questions and issues that should be handled by different organizational bodies – RE bodies for ethical issues in research (most often related to conducting research with animals and human participants), and RI bodies for issues related to good research practice and professional standards (e.g., good authorship and publication practices, data management, peer review, etc.). Publications included in this scoping review emphasized as important for RI promotion and implementation the existence of specialized RI bodies that will deal explicitly with RI issues (178, 196). This imposes the questions how to effectively establish these bodies and what resources organizations should invest. Organizations can learn by example of other research organizations that have successfully established RI bodies and follow these best practices.

Organizations can also develop their RI promotion plans that can help them assess the needs and available resources, and based on that develop RI practices and structures accordingly.

Many articles included in this scoping review referred to negative factors of publish or perish and other pressures, as well as commercialization of research (180, 230). Although some authors argue that pressure to publish has less impact on occurrence of misconduct compared to inadequate misconduct policies, norms values in research culture, and career stage (178), other studies showed that pressure to publish is till perceived by a great number of researchers as the main reason for breaching the RI rules (105, 182, 194). A pressure to publish is a long term issue in the RI field, ands as mentioned in the introduction of this thesis, it is interesting to see that some articles addressing publication pressure date from 90s (121, 122), and the same issues are present today (123–126). This seems to indicate that the scientific community still has no proper solution on how to avoid pressure-related misconduct. However, the last decade was fruitful when it comes to initiatives focused on preventing and avoiding publication pressure. The Declaration on Research Assessment (231), the Leiden Manifesto (232), and the Hong Kong Principles for assessing researchers (54) propose steps that research organizations and the scientific community can take to minimize and avoid publication pressures. Some organizations have already made changes in this area. For example, Ghent University and Utrecht University abandoned researchers' evaluations based on the impact factor of published articles (233, 234), and focused more on the open science initiatives conducted by researchers and their general contribution as scientists.

Collaborations established between universities and industry to conduct research were often mentioned across biomedical publications included in our scoping review. Intense and frequent, often profitable, collaborations between universities and industry made plenty of research applicable in practice and contributed to the overall progress of science and wellbeing of society (230). However, there is also a dark side related to industry funded research and that is often related to financial and other types of conflict of interest, lack of independence from industry and biased research publications, as well as commercialization of research or doing research mainly for financial gain. These are of course seen as factors that have a negative impact on implementation of RI (229, 235, 236). Research has shown that universities and industry often have differing visions on what RI or research misconduct is, but thanks to the continuously developing field of RI today we know that some practices could help align visions

of these stakeholders and help them ensure objectivity and trustworthiness of research publications (180). RI education, which covers the topic of conflict of interest and importance of declaring the conflict openly in research publications is of paramount importance, as well as the organizations' responsibilities to develop and implement conflict of interest policies (180, 188). The mapping of the studies concerning the university-industry relationship and the identification of the positive and negative factors done in this scoping review could benefit the development of educational programs that would be tailored to the needs of researchers and representatives of the industry.

Strengths and limitations

The main strength of this study, as for the previous scoping review, is the comprehensive literature search that enabled development of a comprehensive map of various factors that influence RI promotion and implementation. Peer-reviewed documents from bibliographic databases were searched based on a sensitive search strategy (to increase the comprehensiveness) and screened by multiple researchers, following the robust methodology. This enabled the collection of publications from different disciplines, geographic areas and research organizations.

Since a sensitive search strategy instead of specific was used, the search retrieved a large number of documents from bibliographic databases from which a great number were excluded in the process of screening. However, employing the sensitive search strategy was a better approach as a more precise search strategy would limit the search, and perhaps would not provide as many articles relevant to the study aim. Although the rigorous screening methodology was employed, there is still a possibility that some articles were missed in screening the titles and abstracts. Nonetheless, this risk was minimized by additionally screening the references of included articles which provided the study with as many as possible articles related to the study aim. Another limitation for this study was the period to which the search was confined (1990-2021). The COVID-19 pandemic hit around the same time the scoping review was being done, thus the scoping review may have missed the studies on research misconduct that have arisen during this public health crisis. While the most infamous cases of misconduct seem to be related to issues handled by the studies analyzed in the present scope – such as pressure to publish, relations with industry, conflicts of interest – future research will hopefully shed more light on whether new factors have come into play.

Conclusions

This study showed the existence and interrelatedness of factors that can have a positive or negative impact on RI promotion and implementation among researchers, research organizations, and systems of science. Based on the presented results, it is obvious that solutions for RI should not be focused at only one level of applicability as this will not yield long-term benefits. The research world is an ecosystem that requires efforts from all stakeholders involved. Researchers should follow guidance documents provided to them by national establishments of their research organizations. At the same time research organizations should ensure an optimal process for the development and implementation of guidance documents that will be tailored to the needs of researchers who will be in need to use them. Together with funders and scientific publishers, researchers and research organizations should work toward improving the system of science by promoting initiatives aimed at reducing pressures and competition that lead to research misconduct. The system of science should be built on the culture of integrity, honesty, trustworthiness, and fairness in research. Taking into account that analysis of RI interventions conducted in this study showed lack of reliable evidence regarding the effectiveness of different RI interventions, future research should address this gap by examining what is all that can positively influence RI promotion and implementation among researchers, research organizations, and in the system of science.

6.4. Qualitative study on development and implementation of research integrity documents and practices in biomedicine and other disciplinary fields

The results of this qualitative study showed that researchers and other stakeholders with expertise and experience in the RI field do not see SOPs as currently common RI guidance, but they think SOPs could be valuable for promoting and implementing RI. However, if RI guidance should be more in the format of SOPs, the research community should consider how to optimize these guidance to avoid having a large number of very detailed RI guidance documents. In participants' opinion SOPs and other specific, step by step guidance should be used together with more general guidance that is based on fundamental principles and values. Moreover, in participants' opinion, besides creating detailed RI guidance it is also important support the implementation processes of these guidance documents since implementation is essential for fostering RI. The main challenges that should be addressed in future policy and practice include harmonizing approaches to RI, including researchers in the process of development of RI guidance documents and developing initiatives aimed at changing evaluation practices that should be more focused on RI standards.

One concern mentioned by study participants was the lack of standardized or harmonized approaches to RI. The participants mostly focused on conceptual harmonization in terms of how, for example detrimental research practices are defined across countries, disciplines, and research organizations. Although RI entails more than just poor research behavior, one of the reasons why participants in this study were focused only on this aspect of RI could be because lack of uniformity in defining these practices and different interpretations lead to different application of fundamental RI principles and different consequences for researchers involved in these practices. Of course, since RI is a global endeavor in which research community strives to equal, highest standards of RI the differences in approaches when defining poor research behavior are very problematic. According to the participants, not having standardized approaches to these issues in a wider community affects how RI is accepted and implemented where research is performed – in research organizations. The lack of harmonization was intensively discussed throughout the literature in recent years (3, 85, 237) . Even in places where some harmonization could be expected, for example within the European Union and under the framework outlines in the European Code of Conduct for RI, there is still diversity between countries and research organizations and the definitions of what behavior is

detrimental research (30, 83, 98). This issue is not specific for Europe, as other countries, outside the Europe face similar issues (3, 38, 44, 101, 102). Research community should work on adequately defining RI concepts to create more specific guidance on avoiding detrimental research behavior and encouraging good research practices. In that context, some authors argued whether having properly defined good research practices may reduce or diminish research misconduct and detrimental research practices (238). If we take into account that compliance with RI guidance influences behavior (226), we may question whether the research community needs to define research misconduct and detrimental research practices and achieve absolute harmonization. Or perhaps these poor research practices could be more simply captured by defining them as practices that don't meet the principles of RI, which could help the research community harmonize better since there would be fewer terms and definitions. It is optimistic and probably not feasible to achieve harmonization on every RI issue because it is important to take into account local contexts (e.g., characteristics of disciplines or research organizations' needs), however harmonizing as much as possible should be an objective.

Having fewer definitions could help harmonization, however defining poor research behavior merely as "practices that do not meet the principles of RI" could lead to variety of interpretations and inconsistencies what is already an issue in RI field. Maybe the first step towards harmonization could be agreeing on behavior that is considered as detrimental research practice and the second step should include research organizations integrating these definitions into their guidance documents. Finally, another step in this process should include development of more detailed oriented guidance documents, such as SOPs on how to avoid detrimental research practices. Tailored guidance should also be an imperative. Developing SOPs for different RI topics, tailored to the needs of scientific discipline could help ensuring harmonization of approaches to RI within the same scientific discipline.

When questioned about SOPs, participants named different guidance documents as SOPs. Hence, it was noticeable that SOPs are not common type of RI guidance document. Moreover, participants had very different understanding of SOPs. Some considered SOPs documents that were explicitly called SOPs, while others thought of SOPs as any document that is detailed enough and fits into formal definition of SOP. This is not unusual if we take into account results from other studies that showed lack of strict rules on how guidance is presented in guidance documents (e.g., general or specific, aspirational or normative) (83, 100). The

participants most often mentioned reporting guidelines as SOPs. Reporting guidelines, although not explicitly called SOPs could fit into definition of SOPs. Reporting guidelines are tools aimed at achieving uniformity, transparency, and high quality of performing specific task. Their values is in helping researchers to publish minimum amount of information about the study required for its critical assessment. Hence, reporting guidelines contribute to the completeness and transparency of research output and the reproducibility of research results (239, 240). SOPs have similar aim as they describe in steps how something should be done and responsibilities of those involved in that process, hence aiming that the same action is performed equally each time and that quality of the output is ensured (241, 242). Important difference between guidelines and SOPs is that guidelines are often not mandatory but implemented to guide their users on best approaches and practices, while SOPs are usually developed and implemented as compulsory for their users. To put in context, we can take the example of reporting guidelines. While reporting guidelines have improved the transparency and completeness of research reporting in health (243), these effects are suboptimal mostly because reporting guidelines are implemented by journals only as a formality, without a clear explanation of their importance and instructions on how to use them (244, 245).

Besides reporting guidelines, other RI guidance documents could also be considered as SOPs for RI. For example, the Australian Guide to Managing and Investigating Potential Breaches of the Australian Code for the Responsible Conduct of Research (246) provides enough details and could be considered an SOP for research organizations. This document sets the model which research organizations should follow in the cases of breaches of the Code and describes the responsibilities of different stakeholders, and provides a checklist with defined tasks. The guide is also mandatory for research organizations although it leaves a certain amount of freedom so that research organizations can tailor the model to their legal framework, processes, and agreements established in the workplace. Another example is the UK Self-Assessment Tool for The Concordat to Support RI (247) which provides comprehensive guidance for research organizations and researchers on how to put high-level RI statements into practice. The tool contains a list of self-assessment questions and checklists addressing different RI topics, thus providing step-by-step guidance in dealing with various RI issues. The participants in the interviews also mentioned codes of conduct and general guidelines, such as the European Code of Conduct for RI (37) and Singapore Statement on RI (49, 248) as examples

of SOPs, although these documents are broad, general, and aspirational and cannot be considered as SOPs. Nevertheless, the participants emphasized the importance of principle-based and more general guidance documents since these can be applicable in different contexts, such as different scientific disciplines. On the other hand, more detailed documents, such as SOPs, provide comprehensive and specific guidance that cannot be universally applicable but is rather focused on certain disciplinary field, research organization or research process. The participants emphasized the importance of having both – general and detailed RI guidance. SOPs should be embedded in more general, aspirational guidance that contains principles and values instead of specific rules. The broad guidance can help researchers understand the value and importance of RI and should serve as a basis for developing more detailed and specific guidance for RI. Although official policy framework or hierarchy for guidance documents in the RI field does not exist, the need for coexistence of general and detailed RI guidance is perhaps evident from some initiatives, such as one initiative by the European Commission. Horizon Europe applicants are required to make mandatory declarations, one of which is the declaration that the research complies with RI principles prescribed in the European Code of Conduct for RI (51). Further, applicants must also confirm that they have "appropriate procedures, policies, and structures" in place to ensure compliance with the Code. The SOPs could be such specific procedures and policies that will enable the implementation of the principles and good practices addressed in the Code in research organizations.

The participants in this study also mentioned that developing detailed guidance documents for RI surely comes with some resourcing and governance challenges.

Developing SOPs for different RI issues, and regularly updating these documents to ensure their quality and applicability in practice requires financial and human resources at disposal. This may be an issue for research organizations that do not have that much resources to dedicate to RI. However, because of the importance of RI for science, research organizations should try find or allocate already existing resources to work on development of guidance documents, such as SOPs. This would perhaps require some balancing and prioritizing by research organizations t6o decide which RI issues require attention first. Also, research organizations do not have to start from scratch as many guidance documents already exists, hence organizations can use already existing guidance as inspiration or implement the same guidance it fits the needs of researchers working in that organization. Besides resourcing and governance challenges, the

participants emphasized other issues that should be taken into account when developing RI guidance documents, such as SOPs. It is important that RI guidance documents are understandable and close to practice so that researchers perceive them as relevant and use them when conducting research. If researchers do not perceive RI guidance documents as relevant , they may consider them as an administrative burden and avoid the use of the guidance in practice. These examples of avoiding using guidance documents have already been documented in literature (96, 249). Moreover, the literature also shows differences in how researchers and those who develop RI guidance documents understand RI, which can also influence researchers-perceptions and usage of RI guidance documents (85). Hence, including researchers in developing RI guidance documents is considered a way of ensuring that RI guidance is applicable in real life setting and that researchers will use it. This was also confirmed by participants in this study. Besides including researchers in the process of developing RI guidance documents, it is important also to have proper processes for implementing RI guidance documents. According to the participants in this study, RI education is essential in this aspect. The participants referred to RI as a state of mind which includes an internalized understanding of RI principles and willingness to adhere to RI guidance, which can be acquired through continuous and tailored education. However, the available evidence considering the effectiveness of RI education is rather contradictory, as presented also in the scoping review included in this thesis. Besides the presented scoping review, other meta-analysis and systemic reviews showed the lack of evidence to support the claims on the positive effect of RI education on shaping researchers behavior, while qualitative research showed that RI education helps to raise researchers' awareness and to motivates researchers to think more about RI in their research (250–253). Nevertheless, the participants in this study think that RI education is very important for proper implementation of RI and RI guidance documents and that RI education should be carefully planned and continuously conducted. In addition, the participants advocated for more interactive approaches to RI education that will be conducted in smaller groups and with the use of real-life examples followed by researchers' reflection and evaluation.

Another important factor was mentioned by participants as relevant for RI promotion and implementation. That is the role of researchers and other stakeholders in promoting RI and developing the environment and culture in which RI principles will be in the core of every research. However, not all stakeholders are always aware of their responsibilities related to RI.

The participants advocated for the establishment of RI bodies within research organizations that should be the first contact point for researchers facing with RI issues. As previously presented in the country report cards study, the information on the existence of the RI bodies is scarce, which is also indicated by some other studies (32, 254). This may point out the lack of the national and organizational commitment in this area. Besides the need for RI bodies, the participants also expressed the need for change in evaluation metrics, which should be shifted from quantitative to more qualitative and RI oriented approach. Currently existing evaluation and incentives systems in academia are often seen as factors encouraging research misconduct, as presented in the scoping review on factors affecting RI implementation. The current evaluation systems together with incentives system contribute to unhealthy research culture and over-competitive environment dominated by the pressure to publish (255, 256). Although these issues are an old problem (as previously outlined in the scoping review) it seems that research community needs to work more on finding the solution to these problems. Previously mentioned initiatives like the Leiden Manifesto for research metrics (232), San Francisco Declaration on Research Assessment (231), the Hong Kong Principles for assessing researchers (54), and Science Europe Recommendations on Research Assessment Process (257) can help to achieve this aim.

Further, as research organizations do not operate alone in the research ecosystem (33) funding organizations and scientific journals also have important role in strengthening RI promotion and implementation. The participants in this study talked about the need of having these stakeholders more invested in RI promotion as well. In addition to funders making the clear requirements for obtaining funding that will also include RI requirements, study participants also emphasized the need for more post-research evaluation by funders, which should include, among other factors, the adherence to RI requirements. Moreover, the participants in this study emphasized a great role of scientific journals and publishers in promoting RI. Primarily this can be done by ensuring the integrity of the published record, particularly timely and clearly visible retraction of fraudulent research and correction of published errors. Although some scientific journals have retraction policies and procedures (44, 258), the participants in this study were concerned about the fact that many retractions are often done in silence which is also confirmed by the available literature (259, 260). In addition to retractions, other initiatives by journals could include introduction of authorship statements that

will enable higher transparency, integrity, and accountability of individual contributions and help avoid or reduce potential authorship disputes. Further, open access and data practices are today implemented by many journals as these practices increase the visibility and transparency of research, and provide opportunities for verification and reproducibility of research results. There are also efforts to improve the collaboration between the scientific journals and research organizations on fostering RI and preventing research misconduct (261).

Study strengths and limitations

This is the first qualitative study exploring the role of SOPs in RI and their potential to be important guidance document for promoting RI in future. The main strength of this study is related to the inclusion of participants from various disciplinary and organizational background which enabled collection of important knowledge on various approaches to RI and a glimpse into different perspectives on RI guidance documents, depending on the disciplinary background. Small qualitative studies usually comprise 6-10 interviews, while big qualitative studies are considered those with 20 and more conducted interviews (262). Hence, this study, which consisted of 23 interviews is a big qualitative study that collected sufficient information related to the study aim and research questions. One limitation of this study is lack f representatives from funding organizations who were hard to recruit in the bigger number. Because of this, it was not possible to completely explore RI guidance documents, including SOPs, in funding organizations which was one of our study's objectives. Moreover, this could also mean that the study did not manage to get more insight into how research funders deal with RI issues and how they organize internal RI structures and processes. However, the study was still able to obtain information on funders' initiatives known to the research community and participants were able to identify issues that funders need to address in future.

Conclusions

RI is a global endeavor and the responsibility of all stakeholders included in the research process. Researchers are not solely responsible for how well or poor RI guidance documents, and RI in general are implemented. In the interview participant's words: "The rotten apples are the result of an unhealthy garden. To reduce the number of rotten apples, we must develop a healthy research culture". One way of developing healthy research culture is to invest efforts in developing more optimal RI guidance documents as well as making changes within research

community that will reduce pressures and unhealthy competition that all researchers are exposed to and forced to be part of it in order to maintain academic career. Developing SOPs could be seen as a way of helping researchers create better research culture,, however those in charge for their development should do this process in cooperation with researchers rather than just adding more administrative documentation for researchers.

6.5. General discussion and conclusions

This thesis aimed to provide insights on improving the RI guidance documents and implementation processes of RI in biomedicine by exploring the characteristics of existing RI documents, factors influencing the implementation of RI, and RI framework conditions that impact the overall development of RI. To achieve this, research questions were presented:

1) What are the existing RI guidance documents available in biomedicine and other disciplines (natural sciences, social sciences, and humanities), and what are the main characteristics of these documents depending on the disciplinary origin?;

2) What influences the promotion and implementation of RI and RI guidance documents in biomedicine in comparison to other disciplines?;

3) What are the roles of different stakeholders in promoting and implementing RI in biomedicine, and which factors have an essential impact on the promotion and implementation of RI in biomedicine in comparison to other disciplines?;

4) How to improve RI guidance documents and practices for optimal implementation in biomedicine and in generally in research?

First, it is important to emphasize that the comparison between biomedicine and other disciplinary fields in this context was difficult as there was a significant lack of RI literature related to guidance documents and implementation factors from other disciplines. Guidance documents are essential for RI promotion, as they guide researchers, institutions, and other stakeholders in conducting research with integrity and the highest ethical and professional standards. Hence, the findings from the scoping review study showed that RI guidance documents exist in every discipline. However, some disciplines, such as biomedicine, are more advanced or invested in RI than others (100). Biomedicine is the leader in the number of RI guidance documents if we do not consider RI guidance documents that are developed for research in general and could be adapted to any context, including the disciplinary one. This could be due to the nature of biomedical research, which can have devastating consequences for

human health, which was recognized early in the RI field (1, 3). Hence, at the beginning of establishing RI as a field, biomedicine was the focus, as some of the first RI guidance documents originated from biomedicine. Another reason is the connection between RE and RI. RE principles and guidance were established early, and RI continued this development by focusing more on professional standards and expectations of research organizations. As mentioned, although the results included in this study showed that much RI guidance is developed for RI in general and could be applicable in any discipline, based on the qualitative research results included in his thesis, there is a need for more tailored, including disciplinary tailored RI guidance. The guidance that will take into consideration researchers' needs (105). For example, researchers from all disciplines are probably aware that good data management practices are important for their research, however, data management requirements will differ notably for researchers working in the experimental medical or clinical field compared to researchers working in history or philosophy. Moreover, let us take into account research with human participants. Although both biomedicine and humanities may involve research with human participants, biomedical research often includes clinical trials and invasive procedures. At the same time, historians may be concerned with exploring humans through archival materials, which implies completely different data management, data protection procedures, and ethics. Another example is mentoring or supervision. Although core principles of good supervision of junior researchers are established within the general concepts of RI, the supervision practices will differ between those who work closely with their research students in the laboratory every day and those who work more in the field and do not share their working space daily, for example like in the archeology where field work is normality. All this means that RI guidance documents the main goal to guide researchers and other stakeholders and enhance the quality of research, however how this will be achieved might include different steps and procedures depending on the different contexts.

Most of the guidance documents from all disciplines included in the analysis were guidelines. Although guidelines are often exact and provide concrete guidance or course of action for specific tasks or issues, the scoping review results pointed to the lack of consistency in the form of guidelines (and guidance documents in general) regardless of the discipline (105). While some guidelines are very elaborated and specific, others are more general by providing only aspirational or broad guidance on RI, not detailing any specific RI issue. This can be

problematic when certain actions, for example, laboratory or clinical research procedures, require a uniform approach by everyone who conducts that type of research. Here, standardization and guidance in the form of SOPs, detailed step-by-step procedures would be beneficial, as confirmed by the participants in the interview study presented in this thesis (105). SOPs for RI could provide researchers and other stakeholders with clear and concise guidance on how to approach or perform a certain research procedure and ensure the reliability and robustness of conducted research.

Factors influencing RI promotion and implementation were numerous in every discipline, although the literature included in this study was primarily focused on biomedical research (128). Still, there are differences in what influences RI promotion in biomedicine compared to other disciplines. While biomedical literature focuses, as mentioned previously, on personality characteristics, the role of mentors, as well as some systemic factors (incentive systems and pressures), other disciplines, for example, humanities and social sciences, focus on the personal lack of knowledge of RI as well as the lack of organizational efforts in developing and introducing more RI initiatives. Interestingly, situational factors, such as system-affected hyper-competition and pressure, were only sometimes mentioned across humanities, social sciences, and natural sciences. This is in relation to other studies that found that personally perceived and systemic pressures depend a lot on the disciplinary context (194, 263). One reason for differences between these factors could be related to the previously addressed existence of RI guidance documents. As biomedicine has well-established and many RI guidance documents, while other disciplines lack them, it is probably expected that the knowledge level on RI will differ between researchers working in different disciplines, since there is a lack of written guidance and concrete example of RI best practices. Moreover, a lack of organizational effort in promoting RI in some disciplines is also related. One of the crucial organizational roles is the establishment of RI guidance documents, policies, and structures that will create the environment or climate where researchers know about RI principles and standards, as well as the environment with the ethical culture deemed important for properly implementing institutional policies and rules (73, 111). However, as the lack of RI guidance documents was prominent in some disciplines, it indicates that research organizations should invest more efforts in establishing and fostering RI within their structures. This could be done by creating tailored RI guidance, raising awareness through RI education, and establishing RI bodies and other

structures to handle RI inquiries and cases of research misconduct (105, 128). The exploration of RI country frameworks should also be taken into account here. Perhaps countries that invest more resources in research or have national structures and initiatives for promoting RI will also incentivize changes at the disciplinary level or incentivize different research organizations, regardless of their discipline, to develop more optimal guidance documents and establish structures specialized for RI. Unfortunately, we can not expect the changes soon in countries where not so many resources are invested in research in general, and where there is still no clear distinction between RI and RE (127). Interestingly, RI education was recognized across studies from different disciplines as an important factor for implementing and promoting RI. However, same as for the RI guidance documents, there is much emphasis in current RI literature on creating RI education that will be adapted to the researchers' needs and working contexts. Without this, RI education does not seem to be effective in producing some long-term effects when it comes to implementing and fostering RI (105, 110, 219).

Regarding the roles of different stakeholders in promoting and implementing RI, most of the documents concerning this question, and included in the analysis as a part of this thesis, were from biomedicine. So for biomedicine, we can indeed state that funders and journals play an enormous role in fostering RI. The power these stakeholders have in the biomedical research community could be essential for making substantial changes in promoting RI and reducing detrimental research practices. As mentioned previously, putting more emphasis on the quality of research instead of the quantity of research as evaluation criteria for funding or introducing other criteria, such as researchers' implementation of open science and data management practices, is important for improving RI and overall research work. Although there was not much on the funders and scientific publishers in literature from humanities, social sciences, and natural sciences, there are some expectations that these stakeholders can fulfill regardless of the discipline they operate in. These stakeholders can mandate research organizations and researchers to follow RI clauses in grant contracts and make the selection criteria and processes for grant applications more aligned with RI and more transparent, including the transparency on potential conflicts of interest (47, 58).

One last question remains – how to improve RI guidance documents and practices for optimal implementation in biomedicine and generally in research? It is a tricky question, and this thesis does not provide a definite answer but provides some directions on which RI in

biomedicine should go. The results from the studies in this thesis show the need for clarity and more structure regarding biomedical RI guidance documents. Having many RI guidance documents can often be problematic for researchers, especially in collaborative research endeavors and with pressuring schedules. RI practices that are specific to biomedicine and can be uniformed to enhance the reliability and trustworthiness of research should be standardized and developed in the form of SOPs. SOPs have existed for a long time in the clinical setting, for example, in conducting clinical trials or performing medical procedures where standardization is important, as the slightest errors or omissions in performed steps could be fatal (242, 264). Although RI may not be fatal directly for anyone, it is detrimental to science, and as research is translated to practice, errors concerning RI could subsequently lead to fatalities in everyday practice. In order to avoid creating an even larger number of RI guidance documents that will be sub-optimal and considered an administrative burden, some areas of RI could be standardized between the disciplines. For example, there could be an SOP on how authorship is distributed or, more precisely, who deserves to be an author based on their contribution. Biomedicine has very clear International Committee of Medical Journal Editors (ICMJE) standards, but these could also become a standard in other disciplines regardless of the different authorship practices (265). Authorship contribution should be clear and equal to everyone. Moreover, in order to help RI guidance in biomedicine to be more optimal, researchers should be more engaged in the process of development of these practices. This means senior researchers and junior researchers, who often conduct the most significant parts of research daily. Of course, none of this will have too much sense if some systemic changes are not introduced. A degree of publication pressure and competitiveness is beneficial and one of the reasons biomedical research is progressing quickly, however, too many of these have detrimental effects on researchers and science. Over-competitiveness and enormous publication and tenure pressures lead to a decrease in the quality of biomedical research, less rigorous and less reliable science, and an increased likelihood of research misconduct and other detrimental research practices. Publication pressures could be assessed by research organizations using some of the developed tools (266), and based on the findings, policymakers could introduce changes in how to reduce these pressures.

RI in any discipline is a journey and an ongoing effort. We can only imagine that with the growing amount of research and new technologies introduced more and more in research practices, such as artificial intelligence, the new RI challenges will be brought to day light. This

will mean much adapting and optimizing to address the new challenges, so a good foundation in RI guidance documents should exist. Having RI guidance documents that researchers will accept and use is essential. That, paired with a proper implementation process, such as tailored RI education, will continue to improve RI and science.

7. SUMMARY

Aims: Studies described in this doctoral thesis aimed to explore and synthesize information on the promotion and implementation of RI and RI guidance documents in biomedicine compared to other disciplines. The focus was on defining the possible improvements for research integrity guidance and processes aimed at research integrity implementation in biomedicine.

Methods: Country report cards were used for exploring existing research integrity frameworks in Europe, while scoping reviews were employed for exploring and mapping research integrity guidance documents, as well as factors that impact the implementation of research integrity and guidance documents. Explorative semi-structured interviews were conducted with various stakeholders with experience in research integrity to explore more in-depth research integrity guidance documents and implementation processes.

Results: Country report cards showed prominent differences between European countries regarding the national research integrity frameworks and investing efforts in research integrity. A scoping review of research integrity guidance documents showed that many guidance documents exist in biomedicine, however, there are significant differences in their content and structure. At the same time, the scoping review revealed a lack of research integrity guidance documents in other disciplines. A scoping review of factors influencing the implementation of research integrity pointed to some major challenges the biomedical field faces, such as conflict of interest and a competitive and pressuring environment that impacts the quality of research. Developing research integrity guidance documents, establishing research integrity education, and specialized research integrity bodies were seen as factors that can enhance research integrity implementation. Interviews with research integrity experts revealed the need for more structured, disciplinary-tailored guidance based on direct researchers' input.

Conclusion: National structures for research integrity often differ between countries as each country has its legal framework and context, and differences at the national level lead to even more discrepancies between research organizations. Existing research integrity guidance documents are numerous but, at the same time, suboptimal, which influences their implementation in practice. Standard operating procedures seem to be valued by biomedical researchers, although they are still not a usual research integrity guidance in any field but could be developed to standardize some approaches to research integrity.

8. SAŽETAK

Ciljevi: Istraživanja opisana u ovoj disertaciji imaju za cilj istražiti i sintetizirati informacije o dokumentima za promicanje znanstvenoistraživačke čestitosti, kao i informacije o čimbenicima koji utječu na implementaciju ovih dokumenata te same znanstvenoistraživačke čestitosti u biomedicini i drugim znanstvenim disciplinama. Fokus istraživanja bio je pronaći odgovore na pitanja o mogućim poboljšanjima dokumenata za promicanje znanstvenoistraživačke čestitosti, kao i procesa implementacije navedenih dokumenata u biomedicini.

Metode: Za istraživanje postojećih nacionalnih struktura znanstvenoistraživačke čestitosti u Europi korištene su kartice s izvješćima zemalja. Pretražnim pregledima literature identificirani su i procijenjeni dokumenti za promicanje znanstvenoistraživačke čestitosti, kao i čimbenici koji utječu na implementaciju navedenih dokumenata. Kvalitativna studija, u obliku intervjua s različitim dionicima iz područja znanstvenoistraživačke čestitosti provedena je kako bi se detaljnije istražili problemi i potencijalna poboljšanja u stvaranju i implementaciji dokumenata za promicanje znanstvenoistraživačke čestitosti.

Rezultati: Kartice s izvješćima Europskih država pokazale su značajne razlike između država u pogledu nacionalnih struktura za znanstvenoistraživačku čestitost. Pretražni pregled literature o dokumentima za promicanje znanstvenoistraživačke čestitosti pokazao je da navedeni dokumenti postoje u biomedicini u značajnom broju, ali su razlike u strukturi i sadržaju ovih dokumenata značajne. Nadalje, uočen je značajan nedostatak dokumenata za promicanje znanstvenoistraživačke čestitosti u drugim znanstvenim disciplinama. Pretražni pregled literature o čimbenicima koji utječu na promicanje znanstvenoistraživačke čestitosti ukazao je na velike izazove s kojima se biomedicina suočava, a koji uključuju, između ostalog, sukob interesa te veliku konkurentnost i pritiske koji u konačnici utječu na kvalitetu istraživanja. Razvoj dokumenata za promicanje znanstvenoistraživačke čestitosti, obrazovanje u ovom području te uspostava specijaliziranih organizacijskih tijela uočeni su kao čimbenici koji mogu utjecati na poboljšanje promicanja i održavanja visoke razine znanstvenoistraživačke čestitosti. Provedeni intervjui ukazali su na potrebu za dokumentima i smjernicama koji će biti detaljniji te prilagođeni potrebama određene znanstvene discipline.

Zaključak: Nacionalne strukture za znanstvenoistraživačku čestitost značajno se razlikuju između država što dovodi do još veće nejednakosti između istraživačkih institucija. Postojeći dokumenti za promicanje znanstvenoistraživačke čestitosti su brojni, ali često nisu optimalni

za primjenu u praksi. Izrada dokumenata u obliku standardnih operativnih postupaka za promicanje znanstvenoistraživačke čestitosti može pomoći u ujednačavanju pristupa znanstvenoistraživačkoj čestitosti u biomedicini.

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Published manuscripts on which doctoral thesis is based:

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11. APPENDICES

APPENDIX 1: Search strategies for bibliographic databases

a) Scopus

(TITLE-ABS-KEY(research W/3 (integrity OR ethics OR conduct OR misconduct OR malpractice OR manipulation OR fraud* OR honest*))) OR (TITLE-ABS-KEY((scientific OR academic) W/3 (fraud OR ethics OR integrity OR misconduct OR honesty OR dishonesty))) OR (TITLE-ABS-KEY((researcher* OR scientist*) W/3 (integrity OR honest*))) OR (TITLE-ABS-KEY((publication* or publishing) W/3 (ethics OR plagiari* OR falsif*)) OR (TITLE-ABS-KEY((author* OR contribut*) W/3 (undeserv* OR ghost OR guest OR gift*)))) AND ((TITLE-ABS-KEY(code W/3 (ethic* or conduct)) OR (TITLE-ABS-KEY(educat* OR teach* OR train* OR motivat* OR instruct* OR interven* OR promot* OR supervis* OR mentor*)) OR (TITLE-ABS-KEY(course* OR seminar* OR workshop*)) OR (TITLE-ABS-KEY((program* OR plan* OR policy OR rule* OR procedure* OR standard* OR code*) W/3 (formulat* OR develop* OR improve* OR expand*))) OR (TITLE-ABS-KEY(quality control))) AND (TITLE-ABS-KEY((ethics or research or grant or grants) W/3 (committee or committees or commission or commissions))) OR (TITLE-ABS-KEY(research W/3 (organisation* OR organization*)) OR (TITLE-ABS-KEY(universit$ or college or colleges)) OR (TITLE-ABS-KEY (universit* AND (faculty or faculties or school or schools or department or departments or laboratory or laboratories or lab or institut or institute or institutes))) OR (TITLE-ABS-KEY(academic or academia or higher education*))))

b) Web of Science

20 #19 AND #13 AND #6

19 #18 OR #17 OR #16 OR #15 OR #14

18 TS=(academic OR academia OR higher education*)

17 TS=(universit* AND (faculty OR faculties OR school OR schools OR department OR departments OR laboratory OR laboratories OR lab OR institut OR institute OR institutes))

16 TS=(universit* OR college OR colleges)

15 TS=(research NEAR/3 (organisation* OR organization*))

14 TS=((ethics OR research OR grant OR grants) NEAR/3 (committee OR committees OR commission OR commissions))
13 #12 OR #11 OR #10 OR #9 OR #8 OR #7
12 TS=(quality NEAR/3 control*)
11 TS=((program* OR plan* OR policy OR rule* OR procedure* OR standard* OR code*) NEAR/3 (formulat* OR develop* OR improve* OR expand*))
10 TS=(course* OR seminar* OR workshop*)
9 TS=(educat* OR teach* OR train* OR motivat* OR instruct* OR interven* OR promot* OR supervis* OR mentor*)
8 TS=(code NEAR/3 (ethic* or conduct))
7 TS=(guideline*)
6 #5 OR #4 OR #3 OR #2 OR #1
5 TS=((author* OR contribut*) NEAR/3 (undeserv* OR ghost OR guest OR gift*))
4 TS=((publication* OR publishing) NEAR/3 (ethics OR plagiari* OR falsif*))
3 TS=((researcher* OR scientist*) NEAR/3 (integrity OR honest*))
2 TS=((scientific OR academic) NEAR/3 (fraud OR ethics OR integrity OR misconduct OR honesty OR dishonesty))
1 TS=(research NEAR/3 (integrity OR ethics OR conduct OR misconduct OR malpractice OR manipulation OR fraud* OR honest*))

c) Medline

1 Scientific Misconduct/ (5023)
2 Fraud/ (7036)
3 exp Ethics, Research/ (7574)
4 (research adj3 (integrity or ethics or conduct or misconduct or malpractice or manipulation or misleading or mispresent$ or bias$ or fraud$ or honest$ or reliab?l$ or fair$ or impartial$ or selective$)).tw. (15995)
5 ((scientific or academic) adj3 (fraud or ethics or integrity or misconduct or malpractice or manipulation or honesty or dishonesty)).tw. (2418)
6 ((researcher$ or scientist$) adj3 (integrity or honest$)).tw. (92)
7 Plagiarism/ (1214)

8 (plagiari$ or falsif$).tw. (3121)

9 Publication Bias/ (4693)

10 Duplicate Publication as Topic/ (757)

11 Retraction of Publication as Topic/ (594)

12 Peer Review, Research/ (6325)

13 (data adj3 (interpretat$ or inaccura$ or inadequa$ or deceptive or deceit or bias$ or impartial or manipulat$ or misus$ or misleading or mispresent$ or mistreat$ or selective or suppress$ or fabricat$ or fraud$ or falsif$ or false)).tw. (27201)

14 Research Report/ (2769)

15 (report$ adj3 (selective or deceptive or deceit or misleading or inadequate or independent)).tw. (6958)

16 (research adj3 (underreport$ or under-report$)).tw. (43)

17 ((publication$ or publishing) adj3 ethics).tw. (485)

18 (bias adj3 (publication$ or publishing or analys#s or design)).tw. (13061)

19 (publication$ adj3 (rendundant or duplicate or multiple or salami or undeserving)).tw. (875)

20 (inaccura$ adj3 citation$).tw. (17)

21 Authorship/ (5535)

22 ((author$ or contribut$) adj3 (undeserv$ or ghost or guest or gift$)).tw. (258)

23 Conflict of Interest/ (9252)

24 (interest adj3 (conflict or competing)).tw. (4281)

25 or/1-24 (108903)

26 exp guideline/ (31503)

27 guideline$.tw. (304028)

28 exp "Codes of Ethics"/ (5164)

29 (code adj3 (ethic$ or conduct)).tw. (2457)

30 exp Education, Professional/ (282429)

31 exp Teaching/ (80510)

32 exp Curriculum/ (79237)

33 Mentors/ (9918)

34 (educat$ or teach$ or train$ or motivat$ or instruct$ or interven$ or promot$ or supervis$ or mentor$).tw. (2738959)

35 (course$ or seminar$ or workshop$).tw. (612665)

36 Policy/ (2054)

37 exp Policy Making/ (24148)

38 Program Development/ (27358)

39 ((program$ or plan$ or policy or rule$ or procedure$ or standard$ or code$) adj3 (formulat$ or develop$ or improve$ or expand$)).tw. (181855)

40 Quality Control/ (46654)

41 (quality adj3 control$).tw. (50594)

42 or/26-41 (3811000)

43 exp Ethics Committees/ (9027)

44 ((ethics or research or grant or grants) adj3 (committee or committees or commission or commissions)).tw. (13582)

45 (research adj3 organi#ation$).tw. (8560)

46 Universities/ (36926)

47 (universit$ or college or colleges).tw. (416213)

48 (universit$ and (faculty or faculties or school or schools or department or departments or laboratory or laboratories or lab or institut or institute or institutes)).tw. (106436)

49 (academic or academia or higher education$).tw. (129189)

50 or/43-49 (560208)

51 25 and 42 and 50 (6001)

d) PsychINFO

1 fraud/ (809)

2 professional ethics/ (18329)

3 (research adj3 (integrity or ethics or conduct or misconduct or malpractice or manipulation or misleading or mispresent$ or bias$ or fraud$ or honest$ or reliab?l$ or fair$ or impartial$ or selective$)).tw. (11366)

4 ((scientific or academic) adj3 (fraud or ethics or integrity or misconduct or malpractice or manipulation or honesty or dishonesty)).tw. (1345)

5 ((researcher$ or scientist$) adj3 (integrity or honest$)).tw. (77)

6 plagiarism/ (240)

7 (plagiari$ or falsif$).tw. (2533)

8 peer evaluation/ (2761)

9 peer review$.tw. (7868)

10 (data adj3 (interpretat$ or inaccura$ or inadequa$ or deceptive or deceit or bias$ or impartial or manipulat$ or misus$ or misleading or mispresent$ or mistreat$ or selective or suppress$ or fabricat$ or fraud$ or falsif$ or false)).tw. (7597)

11 (report$ adj3 (selective or deceptive or deceit or misleading or inadequate or independent)).tw. (1707)

12 (research adj3 (underreport$ or under-report$)).tw. (17)

13 ((publication$ or publishing) adj3 ethics).tw. (183)

14 (bias adj3 (publication$ or publishing or analys#s or design)).tw. (2638)

15 (publication$ adj3 (rendundant or duplicate or multiple or salami or undeserving)).tw. (150)

16 (inaccura$ adj3 citation$).tw. (13)

17 ((author$ or contribut$) adj3 (undeserv$ or ghost or guest or gift$)).tw. (452)

18 Conflict of Interest/ (564)

19 (interest adj3 (conflict or competing)).tw. (1343)

20 or/1-19 (54985)

21 guideline$.tw. (58798)

22 (code adj3 (ethic$ or conduct)).tw. (2909)

23 education/ (32620)

24 teaching/ (42029)

25 curriculum/ (25054)

26 mentor/ (5836)

27 (educat$ or teach$ or train$ or motivat$ or instruct$ or interven$ or promot$ or supervis$ or mentor$).tw. (1395167)

28 (course$ or seminar$ or workshop$).tw. (200665)

29 exp policy making/ (68897)

30 exp program development/ (8798)

31 ((program$ or plan$ or policy or rule$ or procedure$ or standard$ or code$) adj3 (formulat$ or develop$ or improve$ or expand$)).tw. (67869)

32 quality control/ (1434)

33 (quality adj3 control$).tw. (3335)

34 or/21-33 (1597178)

35 ((ethics or research or grant or grants) adj3 (committee or committees or commission or commissions)).tw. (2402)

36 (research adj3 organi#ation$).tw. (8713)

37 colleges/ (13109)

38 (universit$ or college or colleges).tw. (327580)

39 (universit$ and (faculty or faculties or school or schools or department or departments or laboratory or laboratories or lab or institut or institute or institutes)).tw. (45016)

40 (academic or academia or higher education$).tw. (156810)

41 or/35-40 (451152)

42 20 and 34 and 41 (5330)

APPENDIX 2: Search strategies for grey literature sources

Scoping review on RI guidance documents

a) Open Grey database
Documents were found using the terms 'research ethics' and 'research integrity'. The process of screening included the screening of titles and abstracts, followed by full-text analysis.
b) CORDIS database
Relevant projects were identified using the term 'research integrity'. Projects documents (deliverables, publications, etc.) were screened for the identification of documents related to RI practices.
c) World Conferences on Research Integrity (WCRI)
The search was performed on the web pages of the World Conferences on Research Integrity (WCRI). The aim was to identify suitable conference material, abstracts, PowerPoint presentations from lectures and workshops related to RI practices.
d) United States Office of Research Integrity (ORI)
The search was performed on the ORI web pages. The search aimed to identify publications related to RI and responsible conduct of research (RCR) practices.
e) European Network of Research Integrity Offices (ENRIO)
The search was performed on ENRIO web pages. The search aimed to identify publications containing RI practices.
f) The National Academies of Sciences, Engineering, and Medicine (NASEM)
The search was performed on the NASEM web pages to identify publication related to RI and RCR.
g) Science Europe
The search was performed on the web pages of Science Europe to identify publications related to RI.
h) Mutual Learning Exercise on Research Integrity
The search was performed on the web pages of the European Commission to identify reports published by the Mutual Learning Exercise on Research Integrity working group.
i) League of European Research Universities (LERU)

The search included the screening of the publication Towards a Research Integrity Culture at Universities: From Recommendations to Implementation (Lerouge and Hol 2020).

Scoping review on factor influencing the promotion and implementation of RI

a) CORDIS database
Documents were found by searching and screening projects related to research integrity, research ethics, and responsible conduct of research.
b) World Conferences on Research Integrity
The search of web pages of World Conferences on Research Integrity covered conference materials, abstracts, PowerPoint presentation, and other available materials to identify documents related to our study aim.
c) The National Academies of Sciences, Engineering, and Medicine
The National Academies publications were searchers using the terms research integrity, research ethics, and responsible conduct of research to identify publications relevant for our study aim.

APPENDIX 3: Interview guide

Original version (pilot interview)

First, I would like to thank you for accepting our invitation to participate in this interview. As it was mentioned in the invitation letter, this interview will be conducted as a part of the project SOPs4RI. The aim of the project is to create an online toolbox consisting of SOPs and guidelines for the promotion of research integrity in research performing organizations (RPOs) and research funding organization (RFOs). These SOPs and guidelines will be offered as flexible tools for RPOs and RFOs to develop Research Integrity Promotion Plans.

To be able to create a toolbox containing best practices for RI, in this interview we would like to hear your experience with practices for the promotion of research integrity and their implementation within research organizations. Further, we would like to hear your opinion regarding the influence of research culture and thoughts about research misconduct. I would like to point out that there are no right or wrong answers so please feel comfortable to express your opinion. Your opinion is very valuable to us and will contribute to the further development and the goal of the project. This interview is confidential; hence everything said will be used, as mentioned in the invitation letter, only for the purposes of the SOPs4RI project.

During the interview, I will take notes and the conversation will be recorded. The recording is only to ensure we have all your answers. As we stated in the invitation letter the tapes will be stored for the period of five years after the last publication.

Do you agree for this interview to be tape-recorded?

This interview will last about an hour. If you don't have any additional questions we can start the interview.

1) Can you briefly tell us what behaviour you consider as responsible research conduct and what practices can help researchers to adhere to research integrity and responsible research conduct?

Possible probes:

How can those practices be implemented into research institutions?

How important is for the institution to develop and enforce rules which will be assembled as codes, guidelines and SOPs, and in which good and bad research practices will be described?

In your opinion, should codes, guidelines, and SOPs be optional or mandatory for research institutions and whether researchers should be obligated to adhere to those norms?

2) What would you address as prominent reasons why researchers get involved in research misconduct?

Possible probes:

Is research culture sufficiently detailed and what other practices, other than FFP, would you consider a violation of research integrity and which need to be regulated?

How are factors such as publishing, obtaining funding for research, career perspectives, and the behaviour of supervisors influencing researchers to involve in research misconduct?

3) What would you address as the most important practices for avoiding research misconduct and what can be done by RPOs and RFOs to avoid research misconduct?

Possible probes:

How important is the training of PhD students and their mentors?

In which way research integrity committees should deal with research misconduct?

What do you think about rehabilitation exercises for researchers involved in research misconduct?

How can funding agencies and journals contribute to the avoiding of research misconduct?

4) Which elements of research culture may have an impact on the implementation of RI practices (positive or negative) and what changes within research culture would be desirable?

Possible probes:

Would publishing negative research results have any impact on the reducement of cases of research misconduct?

What are the pros and cons of temporary and permanent job contracts in terms of conducting research and the researcher's career?

Revised interview guide and questions

First, I would like to thank you for accepting our invitation to participate in this interview. As it was mentioned in the invitation letter, this interview will be conducted as a part of the SOPs4RI project. The aim of the project is to create an online toolbox consisting of SOPs and guidelines for the promotion of research integrity in research performing organizations (RPOs) and research funding organization (RFOs). These SOPs and guidelines will be offered as flexible tools for RPOs and RFOs to develop Research Integrity Promotion Plans.

To be able to create a toolbox containing best practices for RI, in this interview we would like to hear your experience with practices for the promotion of research integrity and their

implementation within research organizations. The word ‘practice’ refers to SOPs, guidelines, codes of conduct, charters, checklists, procedures, and policies for research integrity, as well as training methods and education for research integrity and procedures to deal with research misconduct. Further, we would appreciate your opinion regarding the influence of research culture on the implementation of RI practices. The research culture in this context refers to factors as overall quality assurance/peer review system, trends in research funding, national science and ‘RI’ policy, science culture, and concepts such as ‘academic capitalism’, ‘publish or perish culture’, ‘accelerated academies’, ‘mode II’.

I want to point out that there are no right or wrong answers so please feel comfortable to express your opinion. Your opinion is very valuable to us and will contribute to the further development and the goal of the project. This interview is confidential; hence everything said will be used, as mentioned in the invitation letter, only for the purposes of the SOPs4RI project. During the interview, I will take notes, and the conversation will be recorded. The recording is only to ensure we have all your answers. As we stated in the invitation letter, the tapes will be stored for a period of five years after the last publication.

Do you agree for this interview to be tape-recorded?

This interview will last about an hour. If you don't have any additional questions, we can start the interview.

A) Standard Operating Procedures

1. Of the existing practices (SOPs), in the area of research integrity and research ethics, you currently know, which of those practices do you consider useful and universally applicable (among different countries, different scientific fields and different research institutions)?

2. Besides the SOPs you mention, do you know of some innovative SOPs connected with your area of work?

3. Are there SOPs that need to be developed? Do you know of SOPs and practices that are needed but are either not developed or are insufficiently developed?

B) Research culture

1. In your experience, which elements of research culture may have an impact (positive or negative) on the implementation of SOPs? Are there any differences related to research culture between RPOs and RFOs?

2. In your opinion, what determines the successful implementation of SOPs?

3. What should be taken into consideration for successful implementation at the level of an organization and the level of an individual?

4. Are there differences in implementing SOPs between RPOs and RFOs?

APPENDIX 4: Demographic questionnaire used in interviews

As stated in the invitation letter, this questionnaire is a part of the SOPs4RI project task related to the expert interviews. The questions address your demographic data (gender, age, nationality and country of residence) and questions concerning information relevant for research integrity and standard operating procedures (SOPs).

Storage and use of the personal data collected through the questionnaire will be in alignment with the data protection procedures stated in the invitation letter.

Your age (in years): _____

Your gender: a) Male b) Female c) Prefer not to say

Country of residence: _____

1. How are you involved in research?

a) Researcher/educator

b) Member of research integrity committee

c) Funding and process organizations

d) Policymaker

e) Industry

2. Years of work experience related to research integrity: _____

3. Can you specify 3 characteristics of SOPs that are, in your opinion, crucial for their quality? (e.g. if SOPs should be clear, detailed, extensive, up to date, action-oriented etc.)

4. Can you give us an example of SOP containing characteristic you specified above and that is, in your opinion, an example of good SOP for research integrity?

APPENDIX 5: Information letter and informed consent used in interviews

Dear Sir/Madam,

The Horizon 2020 project SOPs4RI aims to contribute to the promotion of excellent research and a strong research integrity culture aligned with the principles and norms of the European Code of Conduct for Research Integrity (ALLEA 2017). We at the SOPs4RI project aim to collect existing standard operating procedures and guidelines and to develop them further for the implementation in research performing organizations and research funding organizations across Europe. We will create an online toolbox taking into account differences between disciplines and countries. The toolbox will present key elements, i.e. standard operating procedures and guidelines, which will help research performing organizations and research funding organizations create their own institution-tailored Research Integrity Promotion Plans (RIPP).

We would like to invite you to participate in this stakeholder consultation via participation in the interview. By agreeing, you commit to participating in the face to face or online interview (depending on your schedule and availability). As this is a Europe-wide consultation, the language of the interview will be English. The interviews will be conducted anytime from March to June.

Hereafter you can read details about the project and the stakeholder consultation so you can make an informed decision whether you would like to participate in the interview or not.

1. The aim of the research

To create a toolbox of standard operating procedures and guidelines for Research Integrity Promotion Plans it is important to gain a better understanding of existing professional rules, practices, and factors influencing their implementation. The interviews with experts in the field of research integrity will provide us with additional knowledge on general elements for fostering research integrity in research performing organizations and research funding organizations. In this interview, we would like to hear your experience regarding practices for the promotion of research integrity and their implementation within research organizations. Further, we would like to hear your opinion regarding the influence of research culture and thoughts about research misconduct. Knowledge gained through the interviews, together with previously conducted literature search, will be used as a basis for the further development of the project and the

discussion for the Delphi survey and focus groups. Ultimately, the knowledge gained in this project will be used for the development of the toolbox, consisting of standard operating procedures and guidelines, which can be applied among different academic disciplines.

2. What do we ask from you?

If you would like to participate, the interview will be conducted by the researcher from the University of Split School of Medicine or project partners. The estimated duration of the interview is up to 1 hour. Before attending the interview, we will ask you to complete a brief questionnaire (sent via email beforehand) about your background: gender, age, role regarding research integrity, years of experience, nationality and country of residence. The questionnaire will also include a couple of open questions about SOPs for research integrity. You can bring the printed survey answers to the interview or fill them in before the interview. If you decide to participate in the online interview, we kindly ask you to send us a filled survey via e-mail.

3. Benefits and risks of participating

Interviews with research integrity experts are essential for the development of the framework for the SOPs4RI project which will enable us to build a toolbox with SOPs and guidelines for the promotion of research integrity. This will help research performing organizations and research funding organizations to create plans with details to foster and promote responsible research practices, avoid detrimental practices and handle misconduct. Thus, by sharing your knowledge and experience you will help us contribute to the development of better science. The risk associated with the interview is that participants may feel uncomfortable to discuss research misconduct and express opinion about possible negative factors influencing implementation of research integrity practices.

To avoid possible risks we would like to point out that information provided during the interview are confidential. Moreover, if you would like to provide an example of research misconduct we advise you not to mention personal information or personal names but rather present an anonymous case. This way the cases presented in the interview will not be directly linked with the specific organization or individuals.

Your personal data provided during the interview will be anonymized in the course of the transcription process. The information provided during the interview will not be linked with a specific participant. The information will be connected only with the type of stakeholder

(researcher, member of the RI committee, funding and process organizations employee, policy-makers or industry employee).

The information provided during the interview will be used only for the purposes of SOPs4RI project.

4. If you decide not to participate or to withdraw from the interview

Participation in the interview is voluntary. If you decide to participate, we kindly ask you to sign the attached informed consent and return it to us via the e-mail. If you have agreed to participate but change your mind, you can withdraw at any point (including during the interview). When you withdraw from the study, all your non-anonymized data will be destroyed. If your data has already been analyzed, the results will be used but the source of the data will not be retrievable.

5. Data processing and storage

Storage and use of the data collected during the interview will be in alignment with the data protection procedures contained in the European Union Law, specifically Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data (General Data Protection Regulation - applicable as of 25 May 2018 in all European Union member states) and Danish Ministry of Higher Education and Science's recommendation in the Danish Code of Conduct for Research Integrity - Section II. 2. 1. i. (https://ufm.dk/en/publications/2014/the-danish-code-of-conduct-for-research-integrity). All data collected through the interviews will be stored on the SharePoint, a web-based collaborative platform, administered by the project coordinator, i.e. Aarhus University. The access to the stored data will be enabled only for the partners of the SOPs4RI consortium.

The ethics approval for conducting all interviews in the Work Package 3 has been obtained by the Ethics Committee at the University of Split School of Medicine. If you decide to participate in the online interview, we would like to point out that the Skype Business platform is GDPR compliant. All collected data will be stored for a period of five years after the last publication. This includes original audio-visual files, transcriptions, signed consent forms and questionnaires. Only anonymized data will be used for analysis.

In line with the open access movement, we will make the anonymized data publicly available on the Open Science Framework. If we notice that there is any data that even after anonymization has the potential to be sensitive, we will send it to you to obtain consent to either

deleting it, anonymizing it further or making it publicly accessible. If you would like to have access to your non-anonymized data (stored encrypted on SharePoint), you can always contact [name and e-mail address of the researcher] to have it sent to you. The findings from the stakeholder consultation will also be published and made publicly available on the Project's page on the https://cordis.europa.eu/en.

6. Financial aspects

There is no fee paid for participation in the study.

7. Do you have any questions?

Please do not hesitate to contact, Prof Ana Marušić MD, PhD, if you have any questions.

If you would like to contact Data Protection Officer at the University of Split School of Medicine for additional information regarding data protection, privacy issues, and use of data in this research please use this address: dpo@mefst.hr.

APPENDIX 6: Research processes and RI topics identified across practices and list of documents in which RI topics were addressed toward RPOs, RFOs, and other policymakers

Research process	RI topics
Research planning	**Authorship (including publication plan)** (Graf et al. 2009; Morris 2010; NASEM 2017; CSE 2018; Wellcome Trust 2018) **Consideration of ethical issues (including risk-benefit assessment)** (WHO 2005; KNAW 2008; UKRIO 2009; Resnik and Shamoo 2011; Euro Scientist 2017; WEF 2018; Wellcome Trust 2018) **Research methodology** (NESH 2016; NASEM 2017; Wellcome Trust 2018; Parder and Juurik 2019; Lerouge and Hol 2020)
Research conducting	**Authorship** (NASEM 2017; NHMRC 2019a; Lerouge and Hol, 2020) **Collaboration** (UKRIO 2009; DFG 2013; Montreal Statement 2013; Danish Ministry of Higher Education and Science 2014; IUA 2014; Duggins Peloso et al. 2015; Boeheme et al. 2016; ALLEA 2017; Euro Scientist 2017; NASEM 2017; University of Tartu 2017; SAMRC 2018; Wellcome Trust 2018; Marušić 2019a; Parder and Juurik 2019) **Conflict of interest** (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine 1993; Lo and Field 2009; UKRIO 2009; Danish Ministry of Higher Education and Science 2014; IUA 2014; Kyoto University 2014; Dade et al. 2015; NENT 2016; NESH 2016; NASEM 2017; University of Tartu 2017; CSE 2018; Toom and Miller 2018; ENERI, ENRIO and OeAWI 2019; Marušić 2019b; NHMRC 2019b; University of Oxford 2019a; USQ 2019) **Data management** (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine 1993; EMA 2002; WHO 2005; Danish Committees on Scientific Dishonesty 2009; National Academy of Sciences, National Academy of Engineering, and Institute of Medicine 2009a; UKRIO 2009; DFG 2013; KNAW 2013; Danish Ministry of Higher Education and Science 2014; IUA 2014; QUB 2014; Hiney 2015; Sallans and Patterson 2015; ALLEA 2017; Aoki et al. 2017; NASEM 2017; University of Tartu 2017; NASEM 2018a; NASEM 2019; Netherlands Code of Conduct for Research Integrity 2018; NHMRC 2018a; SAMRC 2018; Science Europe 2018a; Science Europe 2018b; Wellcome Trust 2018; NHMRC 2019c; Universities UK 2019; Lerouge and Hol 2020; Science Europe 2020; University of Oxford) **Data protection (privacy and confidentiality)** (WHO 2005; UKRIO 2009; Danish Ministry of Higher Education and Science 2014; PhRMA 2014; Epstein and Lascher 2015; NESH 2016; NASEM 2017; University of Tartu 2017; Araki et al. 2018, Eckstein et al. 2018; Penders et al. 2018; University of Oxford 2018b; NHMRC 2019c; University of Oxford 2019b) **Intellectual property and data ownership** (Bertha 1996; EC 2005; Graf et al. 2009; UKRIO 2009; Danish Ministry of Higher Education and Science 2014; QUB 2014; University of Tartu 2017; CSE 2018; Parder and Juurik 2019) **Mentorship/supervision** (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine 1992; National Academy of Sciences, National Academy of Engineering, and Institute of Medicine 1993; EC 2005; UKRIO 2009; DFG 2013; Danish Ministry of Higher Education and Science 2014; NASEM 2017; University of Tartu 2017; Forsberg et al. 2018; NASEM 2018b; Netherlands Code of Conduct for Research Integrity 2018; NHMRC 2018a; SAMRC 2018; WEF 2018; Wellcome Trust 2018; Lerouge and Hol 2020; ENERI)
Research dissemination	**Authorship** (Graf et al. 2009; NASEM 2017; Lerouge and Hol 2020) **Open science** (Science Europe 2013; Hiney 2015; Science Europe 2015; NENT 2016; NESH 2016; ALLEA 2017; NASEM 2017; University of Tartu 2017; Breit et al. 2018; Forsberg et al. 2018; NASEM 2018a; Science Europe 2018b; WEF 2018; Wellcome Trust 2018; Marušić 2019a; NASEM 2019; Parder and Juurik 2019; Lerouge and Hol 2020; Transparify) **Reporting research** (Royal College of Physicians 2007; PhRMA 2014; NENT 2016; Euro Scientist 2017; WEF 2018; NASEM 2019; Lerouge and Hol 2020)
Research evaluation	**Audit** (EMA 2002; WHO 2005; Shimokai et al. 2007; UKRIO 2009; Epstein and Lascher 2015; Schaller-Demers 2015; Science Europe 2017) **Ethical assessment** (Moodie and Marshall 1992; United Kingdom Health Ministers 1995; EFGCP 1997; Fagot-Largeault 2000; McIntosh et al. 2000; Eckstein 2003; WHO 2005; NHREC 2007; Royal College of Physicians 2007; Cleaton-Jones and Wassenaar 2010; NHRC 2011; Nys 2012; Danish Ministry of Higher Education and Science 2014; Epstein and Lascher 2015; Van Andel 2015; Piasecki et al. 2016; Netherlands Code of Conduct for Research Integrity 2018; NHMRC 2018b; SAMRC 2018; Toom and Miller 2018; USQ 2018; WMA 2018; NHMRC 2019d; OHRP 2019; Universities UK 2019; University of Oxford 2019b, ENERI; HHS) **Evaluation of projects** (Institute of Medicine and National Research Council 2002; DORA 2012; Marušić 2019a)

	Peer review (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine 1993; Institute of Medicine and National Research Council 2002; UKRIO 2009; DFG 2013; NASEM 2017; Science Europe 2017; SAMRC 2018) **Quality control** (WHO 1995; EMA 2002; Institute of Medicine and National Research Council 2002; PhRMA 2014; Epstein and Lascher 2015; Breit and Forsberg 2018; Forsberg et al. 2018) **Research metrics** (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine 1992; National Academy of Sciences, National Academy of Engineering, and Institute of Medicine 1993; Hicks et al. 2015; NASEM 2018b; Penders et al. 2018; WEF 2018; Fanelli 2019a; Moher et al. 2019) **Research monitoring** (EMA 2002; Institute of Medicine and National Research Council, 2002; PhRMA 2014; NASEM 2017; NHMRC 2018b; Parder and Juurik 2019)
RI violations and resolutions	**Data protection in investigations** (EPA 2003; IUA 2014; MEXT 2014; NASEM 2017; Science Europe 2017; University of Oxford 2018a; Marušić 2019b; Universities UK 2019) **Detrimental/questionable/poor research practices definitions** (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine 1992; National Academy of Sciences, National Academy of Engineering, and Institute of Medicine 1993; National Academy of Sciences, National Academy of Engineering, and Institute of Medicine 2009b; KNAW 2013; IUA 2014; Antes 2015; Hiney 2015; OeAWI 2015; Schaller-Demers 2015; ALLEA 2017; NASEM 2017; ENERI, ENRIO and OeAWI 2019; Marušić 2019b) **Fabrication, falsification, plagiarism and self-plagiarism definitions** (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine 1992; National Academy of Sciences, National Academy of Engineering, and Institute of Medicine 1993; NSF 2002; EPA 2003; HHS 2005; Harvard Medical School 2005; OECD 2007; National Academy of Sciences, National Academy of Engineering, and Institute of Medicine 2009b; UKRIO 2009; KNAW 2013; IUA 2014; Hiney 2015; Kyoto University 2015; OeAWI 2015; Schaller-Demers 2015; Boeheme et al. 2016; ALLEA 2017; Dwivedi and Tripathi 2017; NASEM 2017; Science Europe 2017; Netherlands Code of Conduct for Research Integrity 2018; University of Oxford 2018a; ENERI, ENRIO and OeAWI 2019; Kyoto University 2019; Marušić 2019b; Universities UK 2019) **Handling research misconduct (complaints and investigations)** (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine 1992; National Academy of Sciences, National Academy of Engineering, and Institute of Medicine 1993; ORI 1995; ORI 1998; ESF 2000; Evans 2000; OSTP 2000; NSF 2002; EPA 2003; EC 2005; Harvard Medical School 2005; HHS 2005; SCJ 2006; OECD 2007; NTU 2008; UKRIO 2008; OECD 2009; UKRIO 2009; ESF 2011; Resnik and Shamoo 2011; TENK 2012; Wager and Kleinert 2012; DFG 2013; GRC 2013; Danish Ministry of Higher Education and Science 2014; IUA 2014; MEXT 2014; Boyd 2015; CSIC 2015; Kyoto University 2015; Boeheme et al. 2016; Israel and Drenth 2016; NESH 2016; Secretariat on Responsible Conduct of Research 2016; ALLEA 2017; Dwivedi and Tripathi 2017; NASEM 2017; Science Europe 2017; University of Tartu 2017; Breit et al. 2018; CSE 2018; Forsberg et al. 2018; Netherlands Code of Conduct for Research Integrity 2018; Toom and Miller 2018; University of Oxford 2018a; Wellcome Trust 2018; ENERI, ENRIO and OeAWI 2019; Kyoto University 2019; Marušić 2019b; NHMRC 2019c; Universities UK 2019; Lerouge and Hol 2020; ENERI) **Sanctions** (NSF 2002; EC 2005; HHS 2005; SCJ 2006; NTU 2008; Danish Ministry of Higher Education and Science 2014; IUA 2014; MEXT 2014; Boyd 2015; Schaller-Demers 2015; Boeheme et al. 2016; Science Europe 2017; Netherlands Code of Conduct for Research Integrity 2018; NHMRC 2018a; SAMRC 2018; ENERI, ENRIO and OeAWI 2019; Kyoto University 2019; Marušić 2019a; Marušić 2019b; Parder and Juurik 2019) **Whistle-blowers protection** (ORI 1995; OSTP 2000; EPA 2003; KNAW 2008; NTU 2008; DFG 2013; NENT 2016; NASEM 2017; Science Europe 2017; Breit et al. 2018; Forsberg et al. 2018; NHMRC 2018b; ENERI; Marušić 2019b; Parder and Juurik 2019; Universities UK 2019)
RI promotion	**Development and implementation of RI practices** (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine 1992; National Academy of Sciences, National Academy of Engineering, and Institute of Medicine 1993; ESF 2000; Institute of Medicine and National Research Council 2002; OECD 2007; National Academy of Sciences, National Academy of Engineering, and Institute of Medicine 2009b; UKRIO 2009; ESF 2011; IAC and IAP 2012; Wager and Kleinert 2012; DFG 2013; GRC 2013; Danish Ministry of Higher Education and Science 2014; MEXT 2014; QUB 2014; Boyd 2015; CSIC 2015; OeAWI 2015; Schaller-Demers 2015; Boeheme et al. 2016; NENT 2016; NESH 2016; Secretariat on Responsible Conduct of Research 2016; ALLEA 2017; NASEM 2017; Science Europe 2017; Breit et al. 2018; Forsberg et al. 2018; NASEM 2018b; NHMRC 2018a; SAMRC 2018; Wellcome Trust 2018; ENERI, ENRIO and OeAWI 2019; ENERI; Kyoto University 2019; Marušić 2019a; Marušić 2019b; NHMRC 2019c; Universities UK 2019; Lerouge and Hol 2020; Science Europe 2020) **Establishment and work of RI/RE bodies** (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine 1992; ESF 2000; NHREC 2007; OECD 2007; Royal College of

	Physicians 2007; NTU 2008; UKRIO 2008; ESF 2011; Nys 2012; Wager and Kleinert 2012; DFG 2013; Danish Ministry of Higher Education and Science 2014; IUA 2014; Medical University of Graz 2014; MEXT 2014; Boyd 2015; CSIC 2015; Hiney 2015; Schaller-Demers 2015; Dwivedi and Tripathi 2017; NASEM 2017; Science Europe 2017; SATORI 2017; Breit and Forsberg 2018; Forsberg et al. 2018; NHMRC 2018a; NHMRC 2018b; Penders et al. 2018; ENERI, ENRIO and OeAWI 2019; Marušić 2019b; Universities UK 2019; Lerouge and Hol 2020; ENERI) **Incentives** (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine 1992; DORA 2012; NENT 2016; ALLEA 2017; Science Europe 2017; Breit and Forsberg 2018; Forsberg et al. 2018; NASEM 2018b; Wellcome Trust 2018; Fanelli 2019a; Lerouge and Hol 2020;) **Research culture** (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine 1992; National Academy of Sciences, National Academy of Engineering, and Institute of Medicine 1993; CEHAT 2000; EC 2005; OECD 2007; National Academy of Sciences, National Academy of Engineering, and Institute of Medicine 2009b; ESF 2011; Resnik and Shamoo 2011; IAC and IAP 2012; Danish Ministry of Higher Education and Science 2014; QUB 2014; CSIC 2015; Hiney 2015; Boeheme et al. 2016; NESH 2016; ALLEA 2017; NASEM 2017; Secretariat on Responsible Conduct of Research 2016; University of Tartu 2017; Breit et al. 2018; Forsberg et al. 2018; Netherlands Code of Conduct for Research Integrity 2018; Toom and Miller 2018; WEF 2018; Wellcome Trust 2018; Parder and Juurik 2019; Universities UK 2019; Lerouge and Hol 2020) **RI training and education** (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine 1992; National Academy of Sciences, National Academy of Engineering, and Institute of Medicine 1993; CEHAT 2000; Institute of Medicine and National Research Council 2002; EC 2005; SCJ 2006; OECD 2007; Royal College of Physicians 2007; NTU 2008; UKRIO 2009; ESF 2011; NIH 2011; IAC and IAP 2012; GRC 2013; KNAW 2013; NAE 2013; Danish Ministry of Higher Education and Science 2014; ICSU 2014; IUA 2014; MEXT 2014; QUB 2014; Antes 2015; Boyd 2015; CSIC 2015; Hausbeck Korgan 2015; Hendrickson 2015; Hiney 2015; Kyoto University 2015; Schaller-Demers 2015; Boeheme et al. 2016; Foeger and Zimmerman 2016; Israel and Drenth 2016; NESH 2016; Secretariat on Responsible Conduct of Research 2016; ALLEA 2017; NASEM 2017; Science Europe 2017; University of Tartu 2017; Breit et al. 2018; Forsberg et al. 2018; NASEM 2018b; Netherlands Code of Conduct for Research Integrity 2018; NHMRC 2018a; Toom and Miller 2018; WEF 2018; Wellcome Trust 2018; Fanelli 2019b; Kyoto University 2019; NASEM 2019; NHMRC 2019c; NHMRC 2019d; Parder and Juurik 2019; Universities UK 2019; Lerouge and Hol 2020; Science Europe 2020; ENERI)

ALLEA – All European Academies; CEHAT – Centre for Enquiry into Health and Allied Themes; CSE – Council of Science Editors; DFG – Deutsche Forschungsgemeinschaft.; DORA – Declaration on Research Assessment; EC – European Commission; EFGCP – European Forum for Good Clinical Practice; EMA – European Medicines Agency; ENERI – European Network of Research Ethics and Research Integrity; ENRIO – European Network of Research Integrity Offices; EPA – Environmental Protection Agency; ESF – European Science Foundation; GRC – Global Research Council; HHS – Department of Health and Human Services (United States); IAC – Inter Academy Council; IAP – Inter Academy Partners; ICSU – International Council for Science; IUA – Irish Universities Association; KNAW – Royal Netherlands Academy of Arts and Sciences; MEXT – Ministry of Education, Culture, Sports, Science and Technology (Japan); NAE – National Academy of Engineering (United States); NASEM – National Academies of Sciences, Engineering, and Medicine (United States); NENT – National Committee for Research Ethics in Science and Technology (Norway); NESH – National Committee for Research Ethics in the Social Sciences and the Humanities (Norway); NHMRC – National Health and Medical Research Council (Australia); NHRC – Nepal Health

Research Council; NHREC – National Health Research Ethics Committee (Nigeria); NIH – National Institutes of Health; NSF – National Science Foundation (United States); NTU – Nanyang Technological University; OeAWI – Austrian Agency for Research Integrity; OECD – Organisation for Economic Co-operation and Development; OHRP – Office for Human Research Protections (United States); ORI – Office of Research Integrity (United States); OSTP – Office of Science and Technology Policy (United States); PhRMA – Pharmaceutical Research and Manufacturers of America; QUB – Queen's University Belfast; RI – Research Integrity; SAMRC – South African Medical Research Council; SATORI – Stakeholders Acting Together On the ethical impact assessment of Research and Innovation; SCJ – Science Council of Japan; TENK – Finnish National Board on Research Integrity; UK – United Kingdom; UKRIO – United Kingdom Research Integrity Office; US – United States; USQ – University of Southern Queensland; WEF – World Economic Forum; WHO – World Health Organization

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APPENDIX 7: The list of practices aimed at individual researchers classified by research processes and RI topics

Research process	RI topics
Research planning	**Applying for financial resources** (University of Tartu 2017; SAMRC 2018; Path2Integrity) **Authorship and publication plan** (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine 1993; Albert and Wager 2003; Danish Committees on Scientific Dishonesty 2009a; Graf et al. 2009; IADR 2009; UKRIO 2009; ESF 2011; Swiss Academies of Arts and Sciences 2013; University of Wollongong 2017; Wellcome Trust 2018; Matheson 2019; NHMRC 2019a; USQ 2020) **Consideration of ethical issues (including risk-benefit assessment)** (United Kingdom Health Ministers 1995; CEHAT 2000; Mcintosh et al. 2000; Eckstein 2003; RCN 2004; UNESCO 2004; EC 2005; Korenman 2006; Macrina 2007; Royal College of Physicians 2007; KNAW 2008; UKRIO 2009; NHRC 2011; Resnik and Shamoo 2011; Wager and Kleinert 2011; Medical University of Vienna 2013; WMA 2013; Danish Ministry of Higher Education and Science 2014; PhRMA 2014; NENT 2016; The National Committee for Research Ethics on Human Remains 2016; ALLEA 2017; University of Tartu 2017; Borgeat et al. 2018; Eckstein et al. 2018; NENT 2018; Netherlands Code of Conduct for Research Integrity 2018; Penders et al. 2018; TRUST 2018; Wellcome Trust 2018; Parder and Juurik 2019; Universities UK 2019; ENERI decision tree; Path2Integrity) **Research methodology** (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine 1993; Panacek and Lewis 1995; Doherty and Van de Putte 2000; HSRC 2006; Korenman 2006; Northern Illinois University 2006b; Royal College of Physicians 2007; UKRIO 2009; ESF 2011; Resnik and Shamoo 2011; Wager and Kleinert 2011; University of Utrecht 2014; CSIC 2015; Nebeker and Lopez-Arenas 2016; University of Tartu 2017; Netherlands Code of Conduct for Research Integrity 2018; Wellcome Trust 2018; Marušić 2019; NASEM 2019; Parder and Juurik 2019; ENERI decision tree) **Research protocol (including DMP)** (Idänpään-Heikkilä 1994; ESF 2000; Cales et al. 2001; EMA 2002; NIH 2003; Bryn Mawr College 2004; Danish Committees on Scientific Dishonesty 2009a; NHRC 2011; Wager and Kleinert 2011; Medical University of Vienna 2013; WMA 2013; Danish Ministry of Higher Education and Science 2014; NWO 2016; ALLEA 2017; Borgeat et al. 2018; Netherlands Code of Conduct for Research Integrity 2018; Science Europe 2018a; DCC; Path2Integrity) **Research registration** (WMA 2013; PhRMA 2014; Wellcome Trust 2018)
Research conducting	**Authorship** (Harvard Medical School 1991; Friedman 1993; National Academy of Sciences, National Academy of Engineering, and Institute of Medicine 1993; Holaday and Yost 1995; Harvard Medical School 1999; CEHAT 2000; Doherty and Van de Putte 2000; ESF 2000; Cales et al. 2001; Albert and Wager 2003; EC 2005; Macrina 2007; Graf et al. 2009; National Academy of Sciences, National Academy of Engineering, and Institute of Medicine 2009b; UKRIO 2009; Morris 2010; Resnik and Shamoo 2011; Wager and Kleinert 2011; Nichols-Casebolt 2012; DFG 2013; Medical University of Vienna 2013; Swiss Academies of Arts and Sciences 2013; Medical University of Graz 2014; PhRMA 2014; QUB 2014; ACS 2015; CSIC 2015; Hendrickson 2015; OeAWI 2015; EECERA 2015; Israel and Drenth 2016; Matheson 2016; NENT 2016; NESH 2016; ALLEA 2017; Santos et al. 2017; University of Tartu 2017; University of Wollongong 2017; CSE 2018; Netherlands Code of Conduct for Research Integrity 2018; Penders et al. 2018; SAMRC 2018; Matheson 2019; NHMRC 2019a; Parder and Juurik 2019; USQ 2020; ENERI decision tree; Nature; Path2Integrity) **Collaboration** (IADR 2009; UKRIO 2009; Montreal Statement 2013; Hendrickson 2015; ALLEA 2017; NASEM 2017; University of Tartu 2017; Netherlands Code of Conduct for Research Integrity 2018; TRUST 2018; NASEM 2019; Parder and Juurik 2019; ENERI decision tree; Path2Integrity) **Conflict of interest** (CIOMS 1991; National Academy of Sciences, National Academy of Engineering, and Institute of Medicine 1993; Gibinski 1998; CEHAT 2000; Doherty and Van

	de Putte 2000; Cales et al. 2001; Komesaroff 2005; HSRC 2006; Korenman 2006; SCJ 2006; Danish Committees on Scientific Dishonesty 2009a; Graf et al. 2009; IADR 2009; Lo and Field 2009; National Academy of Sciences, National Academy of Engineering, and Institute of Medicine 2009b; UKRIO 2009; ESF 2011; NHRC 2011; Resnik and Shamoo 2011; Wager and Kleinert 2011; Nichols-Casebolt 2012; Medical University of Vienna 2013; Saver 2013; Danish Ministry of Higher Education and Science 2014; PhRMA 2014; QUB 2014; CSIC Manual 2015; EECERA 2015; Hendrickson 2015; OeAWI 2015; Israel and Drenth 2016; NENT 2016; NESH 2016; ALLEA 2017; Santos et al. 2017; University of Tartu 2017; CSE 2018; Penders et al. 2018; SAMRC 2018; Toom and Miller 2018; NHMRC 2019b; Parder and Juurik 2019; Universities UK 2019; University of Oxford 2019a; USQ 2019; ENERI; ENERI decision tree; Nature) **Data management** (Harvard Medical School 1991; National Academy of Sciences, National Academy of Engineering, and Institute of Medicine 1993; Idänpään-Heikkilä 1994; Panacek and Lewis 1995; Gibinski 1998; ESF 2000; Cales et al. 2001; EMA 2002; NIH 2003; Couleham and Wells 2006; SCJ 2006; Danish Committees on Scientific Dishonesty 2009b; National Academy of Sciences, National Academy of Engineering, and Institute of Medicine 2009a; National Academy of Sciences, National Academy of Engineering, and Institute of Medicine 2009b; UKRIO 2009; ESF 2011; Resnik and Shamoo 2011; University of Connecticut 2011; Nichols-Casebolt 2012; DFG 2013; KNAW 2013; Medical University of Vienna 2013; University of Oxford; IUA 2014; Medical University of Graz 2014; QUB 2014; Kreissl Lonfat et al. 2015; Kyoto University 2015; Nebeker and Lopez-Arenas 2016; OeAWI 2015; Israel and Drenth 2016; NESH 2016; ALLEA 2017; Aoki et al. 2017; Garcia Arenillas et al. 2017; University of Tartu 2017; Netherlands Code of Conduct for Research Integrity 2018; SAMRC 2018; Science Europe 2018a; Science Europe 2018b; Toom and Miller 2018; Wellcome Trust 2018; Marušić 2019; NHMRC 2019c; Parder and Juurik 2019; ENERI decision tree; Path2Integrity) **Data protection (privacy and confidentiality)** (CIOMS 1991; Harvey 1994; United Kingdom Health Ministers 1995; Phillips 1999; CEHAT 2000; EMA 2002; Eckstein 2003; NIH 2003; Bryn Mawr College 2004; RCN 2004; HSRC 2006; NITO 2006; Royal College of Physicians 2007; University of Waikato 2008; UKRIO 2009; ESF 2011; NHRC 2011; Wager and Kleinert 2011; WMA 2013; Danish Ministry of Higher Education and Science 2014; IUA 2014; Medical University of Graz 2014; EECERA 2015; NENT 2016; NESH 2016; ALLEA 2017; Santos et al. 2017; University of Tartu 2017; Araki et al. 2018; Eckstein et al. 2018; Penders et al. 2018; SAMRC 2018; TRUST 2018; WEF 2018; Parder and Juurik 2019; University of Oxford 2018b; University of Oxford 2019b; ENERI; ENERI decision tree) **Informed consent** (Harvey 1994; Idänpään-Heikkilä 1994; Nuffield Council on Bioethics 1995; United Kingdom Health Ministers 1995; Phillips 1999; CEHAT 2000; ESF 2000; Fagot-Largeault 2000; Mcintosh et al. 2000; EMA 2002; Eckstein 2003; Maschke 2003; Bryn Mawr College 2004; RCN 2004; UNESCO 2004; de Castilho and Kalil 2005; HSRC 2006; Korenman 2006; NITO 2006; NHREC 2007; Royal College of Physicians 2007; University of Waikato 2008; UKRIO 2009; NHRC 2011; University of Connecticut 2011; Wager and Kleinert 2011; Nys 2012; WMA 2013; PhRMA 2014; EECERA 2015; NESH 2016; Garcia Arenillas et al. 2017; Levy et al. 2017; Borgeat et al. 2018; Penders et al. 2018; Toom and Miller 2018; TRUST 2018; Parder and Juurik 2019; University of Oxford 2019b; ENERI; ENERI decision tree; I-CONSENT; Path2Integrity) **Intellectual property** (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine 1993; ESF 2000; EC 2005; Danish Committees on Scientific Dishonesty 2009a; National Academy of Sciences, National Academy of Engineering, and Institute of Medicine 2009b; UKRIO 2009; University of Connecticut 2011; Danish Ministry of Higher Education and Science 2014; QUB 2014; CSIC 2015; Israel and Drenth 2016; University of Tartu 2017; Crisan and Iacob 2018; Penders et al. 2018; Toom and Miller 2018; Wellcome Trust 2018; Parder and Juurik 2019; Path2Integrity)

	Management of resources (UKRIO 2009; University of Connecticut 2011; QUB 2014; CSIC 2015; EECERA 2015; ALLEA 2017; Kyoto University 2018; Parder and Juurik 2019; Path2Integrity) **Mentorship/supervision** (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine 1992; National Academy of Sciences, National Academy of Engineering, and Institute of Medicine 1993; CEHAT 2000; EC 2005; UKRIO 2009; Nichols-Casebolt 2012; DFG 2013; Danish Ministry of Higher Education and Science 2014; IUA 2014; Medical University of Graz 2014; QUB 2014; CSIC 2015; Hendrickson 2015; Kyoto University 2015; OeAWI 2015; NESH 2016; ALLEA 2017; University of Tartu 2017; NASEM 2018b; Netherlands Code of Conduct for Research Integrity 2018; SAMRC 2018; WEF 2018; Wellcome Trust 2018; Parder and Juurik 2019; ENERI; Path2Integrity) **Protection of research subjects** (CIOMS 1991; Idänpään-Heikkilä 1994; Nuffield Council on Bioethics 1995; CEHAT 2000; EMA 2002; Eckstein 2003; Maschke 2003; RCN 2004; UNESCO 2004; de Castilho and Kalil 2005; HSRC 2006; NITO 2006; SCJ 2006; NHREC 2007; Royal College of Physicians 2007; University of Waikato 2008; IADR 2009; UKRIO 2009; Cleaton-Jones and Wassenaar 2010; University of Connecticut 2011; Nys 2012; Medical University of Vienna 2013; WMA 2013; Medical University of Graz 2014; PhRMA 2014; EECERA 2015; NENT 2016; NESH 2016; ALLEA 2017; Garcia Arenillas et al. 2017; Santos et al. 2017; University of Tartu 2017; Crisan and Iacob 2018; Eckstein et al. 2018; NENT 2018; Netherlands Code of Conduct for Research Integrity 2018; Penders et al. 2018; SAMRC 2018; TRUST 2018; WEF 2018; Wellcome Trust 2018; Parder and Juurik 2019; ENERI; I-CONSENT; Nature; Path2Integrity)
Research dissemination	**Dialogue with public/society** (EC 2005; SCJ 2006; NENT 2016; NESH 2016; Euro Scientist 2017; Netherlands Code of Conduct for Research Integrity 2018; WEF 2018) **Open science** (Panacek and Lewis 1995; ESF 2011; Resnik and Shamoo 2011; ICSU 2014; IUA 2014; QUB 2014; CSIC 2015; NENT 2016; NESH 2016; ALLEA 2017; NASEM 2017; Franck 2018; NASEM 2018a; Toom and Miller 2018; WEF 2018; Wellcome Trust 2018; NASEM 2019; Parder and Juurik 2019) **Publication ethics** (CIOMS 1991; National Academy of Sciences, National Academy of Engineering, and Institute of Medicine 1993; CEHAT 2000; Albert and Wager 2003; UNESCO 2004; EC 2005; HSRC 2006; SCJ 2006; Royal College of Physicians 2007; University of Alabama 2008; National Academy of Sciences, National Academy of Engineering, and Institute of Medicine 2009b; ESF 2011; Wager and Kleinert 2011; DORA 2012; Swiss Academies of Arts and Sciences 2013; WMA 2013; Danish Ministry of Higher Education and Science 2014; ICSU 2014; QUB 2014; ACS 2015; CSIC 2015; Hiney 2015; OeAWI 2015; EECERA 2015; Matheson 2016; NENT 2016; NESH 2016; ALLEA 2017; Santos et al. 2017; University of Tartu 2017; Crisan and Iacob 2018; SAMRC 2018; NHMRC 2019c; Parder and Juurik 2019; Nature; Path2Integrity) **Research reporting (manuscript, reporting guidelines)** (Equator Network; Harvard Medical School 1991; National Academy of Sciences, National Academy of Engineering, and Institute of Medicine 1993; Albert and Wager 2003; UNESCO 2004; Northern Illinois University 2006b; Christiansen et al. 2007; Graf et al. 2009; Wager and Kleinert 2011; Swiss Academies of Arts and Sciences 2013; Medical University of Graz 2014; University of Utrecht 2014; ACS 2015; Bossuyt et al. 2015; Matheson 2016; NESH 2016; NASEM 2019; Nature)
Research evaluation	**Ethics approval** (CIOMS 1991; Doherty and Van de Putte 2000; Fagot-Largeault 2000; Mcintosh et al. 2000; EMA 2002; Eckstein 2003; Maschke 2003; RCN 2004; Korenman 2006; NITO 2006; University of Waikato 2008; National Academy of Sciences, National Academy of Engineering, and Institute of Medicine 2009b; UKRIO 2009; Cleaton-Jones and Wassenaar 2010; NHRC 2011; Wager and Kleinert 2011; Nys 2012; Medical University of Vienna 2013; WMA 2013; Danish Ministry of Higher Education and Science 2014; Medical University of Graz 2014; PhRMA 2014; QUB 2014; NENT 2016; Levy et al. 2017; Penders et al. 2018; NENT 2018; Netherlands Code of Conduct for Research Integrity 2018; SAMRC 2018; Toom and Miller 2018; USQ 2018; University of Oxford 2019b; ENERI; HHS; Path2Integrity)

	Peer review (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine 1993; CEHAT 2000; Doherty and Van de Putte 2000; Northern Illinois University 2006a; UKRIO 2009; Resnik and Shamoo 2011; Wager and Kleinert 2011; Nichols-Casebolt 2012; DFG 2013; Medical University of Graz 2014; QUB 2014; Rockwell 2014; ACS 2015; CSIC 2015; Hendrickson 2015; Israel and Drenth 2016; NENT 2016; ALLEA 2017; University of Tartu 2017; CSE 2018; Netherlands Code of Conduct for Research Integrity 2018; Penders et al. 2018; SAMRC 2018; NASEM 2019; NHMRC 2019d; Parder and Juurik 2019; ENERI; Nature; Path2Integrity)
RI violations and resolutions	**Detrimental/questionable/poor research practices** (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine 1992; National Academy of Sciences, National Academy of Engineering, and Institute of Medicine 2009b; KNAW 2013; IUA 2014; Medical University of Graz 2014; Hiney 2015; OeAWI 2015; ALLEA 2017; NASEM 2017; Netherlands Code of Conduct for Research Integrity 2018; Penders et al. 2018; Universities UK 2019; ENERI) **Fabrication, falsification and plagiarism** (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine 1992; CEHAT 2000; Cockcroft 2000; Doherty and Van de Putte 2000; EC 2005; Korenman 2006; IADR 2009; National Academy of Sciences, National Academy of Engineering, and Institute of Medicine 2009b; UKRIO 2009; ESF 2011; Wager and Kleinert 2011; University of Connecticut 2011; KNAW 2013; Medical University of Vienna 2013; IUA 2014; Medical University of Graz 2014; ACS 2015; EECERA 2015; Hiney 2015; Kyoto University 2015; OeAWI 2015; Roig 2015; NESH 2016; ALLEA 2017; Dwivedi and Tripathi 2017; NASEM 2017; Santos et al. 2017; Netherlands Code of Conduct for Research Integrity 2018; Penders et al. 2018; Toom and Miller 2018; University of Oxford 2018a; Universities UK 2019; ENERI; Nature) **Reporting misconduct** (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine 1992; National Academy of Sciences, National Academy of Engineering, and Institute of Medicine 1993; KNAW 2008; NTU 2008; IADR 2009; UKRIO 2009; Resnik and Shamoo 2011; University of Connecticut 2011; Danish Ministry of Higher Education and Science 2014; ICSU 2014; Kyoto University 2015; University of Tartu 2017; Netherlands Code of Conduct for Research Integrity 2018; University of Oxford 2018a; Wellcome Trust 2018; Marušić 2019; Parder and Juurik 2019; Universities UK 2019) **Whistle-blowing protection** (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine 1992; NTU 2008; DFG 2013; NENT 2016; Parder and Juurik 2019)
RI promotion	**Training and education** (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine 1992; CEHAT 2000; Evans 2000; Alexander and Williams 2004; Macrina 2007; IADR 2009; National Academy of Sciences, National Academy of Engineering, and Institute of Medicine 2009b; UKRIO 2009; NIH 2011; Danish Ministry of Higher Education and Science 2014; Föger and Zimmerman 2016; ALLEA 2017; NASEM 2017; NASEM 2018b; NHMRC 2019c; Path2Integrity) **Research culture** (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine 1992; EC 2005; SCJ 2006; National Academy of Sciences, National Academy of Engineering, and Institute of Medicine 2009b; UKRIO 2009; Danish Ministry of Higher Education and Science 2014; Medical University of Graz 2014; QUB 2014; Wellcome Trust 2018; Parder and Juurik 2019; Path2Integrity)

ACS – American Chemical Society; ALLEA – All European Academies; CEHAT – Centre for Enquiry into Health and Allied Themes; CIOMS – Council of International Organizations of Medical Sciences; CSE – Council of Science Editors; CSIC – Spanish National research Council; DCC – Digital Curation Centre; DFG – Deutsche Forschungsgemeinschaft; DORA – San Francisco Declaration on Research Assessment; EC – European Commission; EMA –

European Medicines Agency; ENERI – European Network of Research Ethics and Research Integrity; ESF – European Science Foundation; HHS – Department of Health and Human Services (United States); HSRC – Human Sciences Research Council; IADR – International Association for Dental Research; ICSU – International Council for Science; IUA – Irish Universities Association; KNAW – Royal Netherlands Academy of Arts and Sciences; NASEM – National Academies of Sciences, Engineering and Medicine; NENT – National Committee for Research Ethics in Science and Technology (Norway); NESH – National Committee for Research Ethics in Social Sciences and Humanities (Norway); NIH – National Institutes of Health (United States); NITO – Norwegian Institute of Biomedical Science; NHMRC – National Health and Medical research Council (Australia); NHREC – National Health Research Ethics Committee (Nigeria); NHRC – Nepal Health Research Council; NWO – Dutch Research Council; OeAWI – Austrian Agency for Research Integrity; PhRMA – Pharmaceutical Research and Manufacturers of America; QUB – Queen's University Belfast; RCN – Royal College of Nurses; SAMRC – South African Medical Research Council; SCJ – Science Council of Japan; UK – United Kingdom; UKRIO – United Kingdom Research Integrity Office; UNESCO – United Nations Educational, Scientific and Cultural Organization; USQ – University of Southern Queensland; WEF – World Economic Forum; WMA – World Medical Association

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APPENDIX 8: Comparison of fundamental principles from the ALLEA code and the NASEM – Fostering Integrity in Research and matching principles found in other documents

Principles from European Code of Conduct for RI	**Principles from the NASEM *Fostering Integrity in Research* book**	**Matching principles identified in other documents**
Reliability (Ensuring the quality of research by proper use of methodology, analysis and resources) (ALLEA 2017)	**Accountability** (Being able to demonstrate the validity of research which will be possible by using a proper methodology) (NASEM 2017)	**Balance** (Wager and Kleinert 2011) **Critical, open-minded approach** (ESF 2000) **Essentiality** (CEHAT 2000) **Excellence** (UKRIO 2009) **High professional standards** (ESF 2000) **Knowledge, ability and commitment to do research** (CEHAT 2000) **Professional competence** (ASA 2018) **Professional integrity** (IADR 2009) **Quality and rigour** (EECERA 2015) **Reliability** (IAC and IAP 2012; Association of Universities in the Netherlands 2012; Wager and Kleinert 2011; IUA 2014; University of Utrecht 2014) **Research merit** (NHMRC 2018b) **Rigour** (NHMRC 2018a; Universities UK 2019) **Scientific and academic professionalism** (HSRC 2006) **Scrupulousness** (University of Utrecht 2014; Netherlands Code of Conduct for Research Integrity 2018) **Scepticism** (IAC and IAP 2012) **Soundness** (Wager and Kleinert 2011) **Training and skills** (UKRIO 2009) **Verifiability** (Association of Universities in the Netherlands 2012)
Honesty (Being honest, fair and transparent in developing, conducting, evaluating and reporting research) (ALLEA 2017)	**Honesty** (Honesty is a prerequisite of good research and other principles) (NASEM 2017) **Objectivity** (Researchers' independence in performing research, avoidance of pressure and biases to be able to present research results truthfully) (NASEM 2017) **Openness** (Being transparent in all researchers phases, presenting all relevant information to other researchers, research participants and society) (NASEM 2017)	**Balance** (Wager and Kleinert 2011) **Communication** (Montreal Statement 2013; IUA 2014) **Cooperation** (UKRIO 2009; University of Tartu 2017) **Fairness** (IUA 2014; TRUST 2018) **Freedom** (University of Tartu 2017) **Honesty** (ESF 2000; IADR 2009; UKRIO 2009; Resnik and Shamoo 2011; IAC and IAP 2012; Wager and Kleinert 2011; Danish Ministry of Higher Education and Science 2014; IUA 2014; University of Tartu 2017; Netherlands Code of Conduct for Research Integrity 2018; NHMRC 2018a; TRUST 2018; Universities UK 2019)

		Impartiality (Association of Universities in the Netherlands 2012; University of Utrecht 2014; IUA 2014) **Independence** (Association of Universities in the Netherlands 2012; IUA 2014; Netherlands Code of Conduct for Research Integrity 2018) **Integrity** (UKRIO 2008; UKRIO 2009; Montreal Statement 2013; EECERA 2015; ASA 2018; NHMRC 2018a) **Justice** (NHMRC 2018a) **Objectivity** (IADR 2009; IAC and IAP 2012; IUA 2014; University of Tartu, 2017) **Openness** (IAC and IAP 2012; University of Tartu 2017; Moher et al. 2019) **Originality** (Wager and Kleinert 2011) **Respectful interactions** (EECERA 2015) **Scrupulousness** (Association of Universities in the Netherlands 2012) **Transparency** (CEHAT 2000; HSRC 2006; Wager and Kleinert 2011; Montreal Statement 2013; Danish Ministry of Higher Education and Science 2014; EECERA 2015; NHMRC 2018a; Moher et al. 2019; Universities UK 2019)
Respect (Respecting colleagues, research participants, society and environment) (ALLEA 2017)	**Stewardship** (Good stewardship toward other researchers, organisation and science overall) (NASEM 2017) **Fairness** (Being fair in research evaluation or toward research participants and animals when conducting research; acknowledging the work of others fairly) (NASEM 2017)	**Appropriate authorship and acknowledgements** (Wager and Kleinert 2011) **Balance** (UKRIO 2008) **Beneficence** (CEHAT 2000; CIOMS and WHO 2009; NHRC 2011; Santos et al. 2017; NHMRC 2018b) **Care** (IUA 2014; University of Tartu 2017; TRUST 2018; Universities UK 2019) **Collaboration** (University of Utrecht 2014) **Consideration** (IADR 2009) **Equity** (EECERA 2015) **Fairness** (ESF 2000; UKRIO 2008; IAC and IAP 2012; NHMRC 2018a) **Frankness** (ESF 2000) **Goals** (Montreal Statement 2013) **Honour** (IADR, 2009) **Inclusiveness** (Moher et al. 2019) **Integrity** (ASA 2018) **Justice** (NHRC 2011; EECERA 2015; Santos et al. 2017; University of Tartu 2017) **Knowing multiple perspectives** (EECERA 2015) **Maximisation of public interest and social justice** (CEHAT 2000)

		Non-exploitation (CEHAT 2000) **Non-maleficence** (CEHAT 2000) **Precaution and risk minimisation** (CEHAT 2000) **Professional courtesy** (Resnik and Shamoo 2011) **Promotion** (NHMRC 2018a) **Prudence** (IADR 2009) **Recognition** (NHMRC 2018a) **Respect (people's rights, dignity, diversity, democratic values, the autonomy of research participants, environment, privacy, anonymity and confidentiality)** (CEHAT 2000; HSRC 2006; UKRIO 2008; CIOMS and WHO 2009; NHRC 2011; EECERA 2015; Santos et al. 2017; University of Tartu 2017; ASA 2018; NHMRC 2018a; NHMRC 2018b; TRUST 2018; Universities UK 2019) **Responsible reporting** (Wager and Kleinert 2011) **Safety** (UKRIO 2009)
Accountability (Researchers and research organisations are responsible for their research and its impact, mentoring, education and training) (ALLEA 2017)	**Accountability** (Being accountable for research behaviour, work and actions; researchers have an obligation to explain the validity of their work, as well as the responsibility of being trustworthy toward organisation and society. Funders are accountable for evaluating research proposals and providing grants) (NASEM 2017)	**Accountability** (CEHAT 2000; HSRC 2006; UKRIO 2009; Resnik and Shamoo 2011; IAC and IAP 2012; Wager and Kleinert 2011; Danish Ministry of Higher Education and Science 2014; NHMRC 2018a; Universities UK 2019) **Contributing to societal needs** (Moher et al. 2019) **Prevention of detriment** (UKRIO 2008) **Public domain** (CEHAT 2000) **Purpose** (Montreal Statement 2013) **Responsibility** (Wager and Kleinert 2011; IUA 2014; University of Tartu 2017; Netherlands Code of Conduct for Research Integrity 2018; Moher et al. 2019) **Resource management** (Montreal Statement 2013) **Roles and responsibilities** (Montreal Statement 2013) **Social contribution** (EECERA 2015) **Social responsibility** (ASA 2018) **Totality of responsibility** (CEHAT 2000)

ASA – American Sociological Association; CEHAT – Centre for Enquiry into Health and Allied Themes; CIOMS – Council for International Organizations of Medical Sciences; EECERA – European Early Childhood Education Research Association; ESF – European Science Foundation; HSRC – Human Sciences Research Council; IAC – Inter Academy Council; IADR

– International Association for Dental Research; IAP – Inter Academy Partners; NHMRC – National Health and Medical Research Council (Australia); NHRC – Nepal Health Research Council; RI – research integrity; UK – United Kingdom; UKRIO – United Kingdom Research Integrity Office; WHO – World Health Organization

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APPENDIX 6: Taxonomy of factors influencing research integrity promotion and implementation and list of publications in which factors were identified

The factors are first organized by level of application, followed by topics and type of impact (positive or negative):

Level: Individual researcher

Environment and culture

Personality traits, personal values, aspirations, and motivation

Knowledge and skills

Level: Research organization

Research environment and culture

Research integrity education and support

Research integrity policies, structures, and processes

Evaluations, incentives, and rewards

Research integrity in funding organizations

Level: System of science

Global research culture

Scientific journals and publishers

Level: Individual researcher		
	Positive	**Negative**
Environment and culture	**The role of mentors, supervisors and senior researchers (role models – e.g., setting positive examples and modeling students' ethical behavior; having regular meetings with students; and providing guidance and help)** (Institute of Medicine, National Academy of Sciences, and National Academy of Engineering 1995; Lenz and Ketefian 1995; Eastwood et al. 1996; Bird 2001; Roberts, Kavussanu, and Sprague 2001; Anderson et al. 2007b; Kalichman 2007; Mumford et al. 2007; Roland 2007; Macfarlane and Saitoh 2008; Mitchell and Carroll 2008; Wright, Titus, and Cornelis 2008; Geller et al. 2010; Alfredo and Hart 2011; Amin et al. 2012; Brown and Agius 2012; Gray and Jordan 2012; Nichols-Casebolt 2012; Ripley et al. 2012; Mahmud and Bretag 2014; Titus	**The role of mentors and supervisors (negative role models – e.g., not paying enough attention to young researchers' work; having pressure to supervise a large number of students; having a lack of appropriate training)** (Hilgartner 1990; Jasanoff 1993; Eastwood et al. 1996; Vijh 1996; Brice and Bligh 2005; Redman and Merz 2005; Anderson et al. 2007a; Anderson et al. 2007b; Davis, Riske-Morris, and Diaz 2007; Kalichman 2007; Mumford et al. 2007; Roland 2007; Macfarlane and Saitoh 2008; Wright, Titus, and Cornelis 2008; Nilstun, Löfmark, and Lundqvist 2010; Werner-Felmayer 2010; Horner and Minifie 2011; Bouter 2015; Fanelli, Costas, and Larivière 2015; Foeger and Zimmerman 2015; NASEM 2017; Buljan, Barać, and Marušić 2018; Ertl

	and Ballou 2014; Foeger and Zimmerman 2015; NASEM 2017; Olesen, Amin, and Mahadi 2017; Buljan, Barać, and Marušić 2018; Ertl 2018; Godecharle, Nemery, and Dierickx 2018; Schrag 2018; Bruton et al. 2020; Knysh et al. 2020) **Organizational leaders setting good examples to researchers (e.g., establishing, promoting, and fostering research integrity policies and practices; fostering and rewarding ethical behavior and behavior that is following research integrity principles; punishing unethical conduct and research misconduct; fostering inclusive communication and environment in which researchers feel free to discuss research integrity issues)** (NASEM 2017; Echols 2017) **Researchers having written agreements defining their research integrity responsibilities and rights** (Binder, Friedli, and Fuentes-Afflick 2016) **A culture of open communication, dialogue, justice, and integrity** (Institute of Medicine, National Academy of Sciences, and National Academy of Engineering 1995; Mumford et al. 2007; Geller et al. 2010; Fanelli, Costas, and Larivière 2015; NASEM 2017) **Awards and promotion requirements tied to research integrity (e.g., bonus plans and award system to reward behavior that is in accordance with research integrity)** (Institute of Medicine and National Research Council 2002) **Having opportunity to anonymously report misconduct (e.g., having procedures and processes for reporting misconduct anonymously; having adequate protection of confidentiality and privacy of whistleblowers)** (Godecharle, Nemery, and Dierickx 2018)	2018; Evans et al. 2018; Godecharle, Nemery, and Dierickx 2018; Olesen, Amin, and Mahadi 2018a; Asman et al. 2019; Fanelli et al. 2019; Haven et al. 2019a; Haven et al. 2019b; Hoole 2019; Satalkar and Shaw 2019; Abbasi et al. 2020; Bruton et al. 2020; Haven et al. 2020; Hofmann et al. 2020; Muthanna and Alduais 2020; Olesen et al. 2020; Abdi et al. 2021; Li and Cornelis 2021) **Precarious position of junior researchers (e.g., power imbalance between junior and senior researchers; junior researchers are afraid to discuss the research and its possible mistakes; junior researchers supporting senior researchers even when they are involved in poor research behavior)** (Eastwood et al. 1996; Davis, Riske-Morris, and Diaz 2007; Mumford et al. 2007; Geller et al. 2010; Nilstun, Löfmark, and Lundqvist 2010; Street et al. 2010; Akpabio and Esikot 2014; Medeiros et al. 2014; Fanelli, Costas, and Larivière 2015; Foeger and Zimmerman 2015; Trinkle et al. 2017; Olesen, Amin, and Mahadi 2018a; Haven et al. 2019a; Malički et al. 2019; Knysh et al. 2020; Abdi et al. 2021) **Perverse incentives (e.g., incentives for publishing a lot of research; focus is on quantity rather than quality of research and on positive research results only)** (Douglas 1993; Roberts, Kavussanu, and Sprague 2001; Redman and Merz 2005; OECD 2007; Macfarlane and Saitoh 2008; Wright, Titus, and Cornelis 2008; Horner and Minifie 2011; Rajeshwari 2011; Amin et al. 2012; Abdollahi, Gasparyan, and Saeidnia 2014; Akpabio and Esikot 2014; Fanelli, Costas, and Larivière 2015; Foeger and Zimmerman 2015; Guraya et al. 2016; Korgan Hausbeck 2016; Gasparyan et al. 2017; Buljan, Barać, and Marušić 2018; Godecharle, Nemery, and Dierickx 2018; Olesen, Amin, and Mahadi 2018a; Olesen, Amin, and Mahadi 2018b; Rahman and Ankier 2020) **Pressure (e.g., work related stressors, competitive environment, academic performance metrics, overload of requirements, collaborative networks' pressure, pressure for meeting**

		deadlines (cutting corners), pressure for PhD students to make significant and original contribution) (Hilgartner 1990; Lombardi 1990; Douglas 1993; Jasanoff 1993; Eastwood et al. 1996; Vijh 1996; Brice and Bligh 2005; Claxton 2005; Martinson, Anderson, and De Vries 2005; Redman and Merz 2005; Newman and Jones 2006; Davis, Riske-Morris, and Diaz 2007; Mumford et al. 2007; OECD 2007; Mitchell and Carroll 2008; Wright, Titus, and Cornelis 2008; Eret and Gokmenoglu 2010; Werner-Felmayer 2010; Zeng and Resnik 2010; Horner and Minifie 2011; Adeleye and Adebamowo 2012; Amin et al. 2012; Masic 2012; Ryan et al. 2012; Sax 2012; Van Dalen and Henkens 2012; Resnik 2014; Tijdink et al. 2014; Bouter 2015; Fanelli, Costas, and Larivière 2015; Foeger and Zimmerman 2015; Gallagher 2015; Antes et al. 2016; Binder, Friedli, and Fuentes-Afflick 2016; Breit and Forsberg 2016; Guraya et al. 2016; Hofmann and Holm 2016; Korgan Hausbeck 2016; Ozcan and Balci 2016; Tijdink et al. 2016b; Echols 2017; Edwards and Roy 2017; NASEM 2017; Pupovac, Prijić-Samaržija, and Petrovečki 2017; Trinkle et al. 2017; Bion et al. 2018; Buljan, Barać, and Marušić 2018; Evans et al. 2018; Felaefel et al. 2018; Godecharle, Nemery, and Dierickx 2018; Olesen, Amin, and Mahadi 2018a; Olesen, Amin, and Mahadi 2018b; Asman et al. 2019; Ayodele, Yao, and Haron 2019; Haven et al. 2019c; Hofmann and Holm 2019; Hoole 2019; Maggio et al. 2019; Aprile, Ellem, and Lole 2020; Bruton et al. 2020; Hofmann et al. 2020; Holtfreter et al. 2020; Mabou Tagne et al. 2020; Muthanna and Alduais 2020; Rahman and Ankier 2020; Zeljic 2021; Li and Cornelis 2021) **Situational factors (e.g., financial and relationship issues)** (Davis 2003; Davis, Riske-Morris, and Diaz 2007; Amin et al. 2012; Nichols-Casebolt 2012; Pupovac, Prijić-Samaržija, and Petrovečki 2017; Trinkle et al. 2017; Olesen, Amin, and Mahadi 2018a; Olesen, Amin, and Mahadi 2018b) **Lack of appreciation for compliance with research integrity requirements**

		(e.g., research organizations do not emphasize research integrity compliance which may demotivate researchers to comply with research integrity policies and practices) (Mumford et al. 2007; Akpabio and Esikot 2014; Foeger and Zimmerman 2015; Buljan, Barać, and Marušić 2018) **Lack of team spirit and poor interpersonal relationships within research team** (Jasanoff 1993; Davis, Riske-Morris, and Diaz 2007; Mumford et al. 2007; Haven et al. 2019b) **Poor chances for getting caught and sanctioned for misconduct** (Davis 2003; Eret and Gokmenoglu 2010; Holtfreter et al. 2020; Mabou Tagne et al. 2020; Li and Cornelis 2021) **Lack of protection for whistleblowers** (Institute of Medicine, National Academy of Sciences, and National Academy of Engineering 1995; Lubalin and Matheson 1999; Redman and Merz 2005; Satalkar and Shaw 2018) **Low salaries** (Chen and Macfarlane 2015) **Environment and culture differences (e.g., existence of various rules and differences between rules; different interpretation of guidance and policies in different setting)** (Lenz and Ketefian 1995; Cribb 2004; Louis et al. 2008; Mitchell and Carroll 2008; Horner and Minifie 2011; Hofmann and Holm 2016; Antes et al. 2018; Olesen, Amin, and Mahadi 2018a) **Lack of independence from industry (e.g., industry funds research, or training and education)** (Resnik and Shamoo 2002; Foote 2003; Miller, Moore, and Strange 2006; OECD 2007; Nichols-Casebolt 2012; Sax 2012; DeCensi et al. 2018; Evans et al. 2018; Godecharle, Nemery, and Dierickx 2018; Schonhaut 2019)
Personality traits, personal values, aspirations, and motivation	**Positive**	**Negative**
	Positive personality traits (e.g., rule following attitude, high moral integrity, honesty, sense of social responsibility, respectfulness) (Kalichman 2007; Macfarlane and Saitoh 2008; Resnik 2014; Tijdink et al. 2016a; Antes et al. 2018; Satalkar and Shaw 2019)	**Negative personality traits (e.g., vanity and self-confidence, sloppiness, greed, over ambition, laziness, impulsivity, cynicism, narcissism, ignorance, ego, lack of sense for morality, naivety, self-justification, self-aggrandizement, Messianic complex, Machiavellianism)** (Jasanoff 1993; Davis 2003; Brice and

	Professional virtues (professional decision-making, critical thinking skills, and intellectual honesty) (Lombardi 1990; DuBois 2004; Kalichman 2007; Antes et al. 2016; Haven et al. 2020) **Positive attitude toward research integrity and research integrity education (e.g., valuing research integrity policies, practices, and education; awareness of the importance of research integrity and research integrity education)** (Jordan and Gray 2012; Azakir et al. 2020) **Willingness to adhere to high professional standards and confidence to use ethical skills** (Institute of Medicine, National Academy of Sciences, and National Academy of Engineering 1995, Kalichman 2007) **Socio-cultural background (e.g., the influence of culture in shaping individual character which may influence how researchers conduct research; existence and adherence to research integrity policies and practices in different cultural settings may positively influence researchers' behavior)** (Fanelli, Costas, and Larivière 2015; Antes et al. 2016; Olesen, Amin, and Mahadi 2017) **Willingness to report research misconduct and other scientific dishonest behavior** (Institute of Medicine, National Academy of Sciences, and National Academy of Engineering 1995; NASEM 1992; Claxton 2005; Allen and Dowell 2013; Hofmann and Holm 2016; Olesen et al. 2019b) **Willingness to disclose conflict of interest** (Barnett 1995; Institute of Medicine, National Academy of Sciences, and National Academy of Engineering 1995; Boyd and Bero 2000; Resnik and Shamoo 2002; Evans and Packham 2003; Lipton, Boyd, and Bero 2004; Horner and Minifie 2011; Bion et al. 2018; DeCensi et al. 2018)	Bligh 2005; Martinson, Anderson, and De Vries 2005; Redman and Merz 2005; Antes et al. 2007; Davis, Riske-Morris, and Diaz 2007; Kalichman 2007; OECD 2007; Mitchell and Carroll 2008; Wright, Titus, and Cornelis 2008; Horner and Minifie 2011; Amin et al. 2012; Masic 2012; Medeiros et al. 2014; Resnik 2014; Bouter 2015; Fanelli, Costas, and Larivière 2015; Antes et al. 2016; Breit and Forsberg 2016; Ozcan and Balci 2016; Tijdink et al. 2016a; Pupovac, Prijić-Samaržija, and Petrovečki 2017; Trinkle et al. 2017; Bion et al. 2018; Buljan, Barać, and Marušić 2018; Godecharle, Nemery, and Dierickx 2018; Olesen, Amin, and Mahadi 2018a; Olesen, Amin, and Mahadi 2018b; Awasthi 2019; Berggren and Karabag 2019; Haven et al. 2019b; Satalkar and Shaw 2019; Abbasi et al. 2020; Holtfreter et al. 2020; Abdi et al. 2021; Li and Cornelis 2021) **Moral and compliance disengagement and abdication of responsibility** (Davis 2003; Medeiros et al. 2014; Schrag 2018) **Wish for recognition, success, and financial gain (e.g., publishing extensively regardless of research integrity requirements, taking shortcuts, weighting consequences of research misconduct and rewards for scientific achievements)** (Claxton 2005; Redman and Merz 2005; OECD 2007; Wright, Titus, and Cornelis 2008; Rajeshwari 2011; Amin et al. 2012; Masic 2012; Fanelli, Costas, and Larivière 2015; Benko 2016; Breit and Forsberg 2016; Aubert Bonn, Godecharle, and Dierickx 2017; Pupovac, Prijić-Samaržija, and Petrovečki2017; Antes et al. 2018; Ertl 2018; Godecharle, Nemery, and Dierickx 2018; Satalkar and Shaw 2019; Abdi et al. 2021) **Taking research integrity for granted (e.g., not agreeing with research integrity requirements and guidelines; perception of research integrity requirements as administrative burden)** (Bhopal et al. 1997; Mitchell and Carroll 2008; Johnsson et al. 2014; Vasconcelos et al. 2015; DuBois and Antes 2018; Evans et al. 2018; Olesen,

		Amin, and Mahadi 2018b; Holtfreter et al. 2020; Li and Cornelis 2021) **Not declaring conflicts of interest (related to career benefits and financial gain)** (Boyd and Bero 2000; Resnik and Shamoo 2002; Foote 2003; Claxton 2005; Bruyere et al. 2010; Horner and Minifie 2011; Foeger and Zimmerman 2015; Abbas et al. 2018; DeCensi et al. 2018; Godecharle, Nemery, and Dierickx 2018) **Unwillingness to accept new things and research requirements** (Horner and Minifie 2011; Buljan, Barać, and Marušić 2018) **Fear of failure** (Claxton 2005) **Poor judgement** (Davis 2003; Mumford et al. 2007; Medeiros et al. 2014) **Lack of ideas for research articles, lack of motivation, and lack of interest in research topic** (Eret and Gokmenoglu 2010; Rajeshwari 2011; NASEM 2017) **Mental and emotional problems** (Davis 2003) **Not reporting misconduct (e.g., because of the fear of consequences)** (Eastwood et al. 1996; Lubalin and Matheson 1999; Nylenna et al. 1999; Rhodes and Strain 2004; Redman and Merz 2005; Steneck 2006; Geller et al. 2010; Horner and Minifie 2011; Resnik and Stewart 2014; Echols 2017; Olesen, Amin, and Mahadi 2018a; Satalkar and Shaw 2018; Olesen et al. 2019b) **Socio-cultural background (in some countries/cultures cheating behavior is more accepted than in others)** (Fanelli, Costas, and Larivière 2015; Antes et al. 2016; Olesen, Amin, and Mahadi 2017)
	Positive	**Negative**
Knowledge and skills	**Having research experience, good knowledge and understanding of research and research integrity** (Nilstun, Löfmark, and Lundqvist 2010; Brown and Agius 2012; Antes et al. 2016; Foeger and Zimmerman 2015; ENERI 2018; Asman et al. 2019; Tessier 2019; Hofmann et al. 2020; Mabou Tagne et al. 2020; Zeljic 2021) **Completing research integrity or responsible conduct of research education (e.g., training for both junior and senior researchers; completing different types of educational courses tailored to the needs; completing**	**Lack of research integrity or responsible conduct of research education (or educational courses being too broad and general; lack of congruity from what is taught in educational courses and how it is in reality)** (Institute of Medicine, National Academy of Sciences, and National Academy of Engineering 1995; Vijh 1996; Anderson et al. 2007b; Powell, Allison, and Kalichman 2007; Vuckovic-Dekic et al. 2012; Titus and Ballou 2014; Antes 2016; Antes et al. 2016; Guraya et al. 2016; Pupovac, Prijić-Samaržija, and Petrovečki 2017; Buljan, Barać, and

	training in research methodology; research integrity education for mentors and supervisors) (Institute of Medicine and National Research Council 2002; Motta 2002; Anderson et al. 2007a; Anderson et al. 2007b; Davis, Riske-Morris, and Diaz 2007; Mayer and Steneck 2007; Powell, Allison, and Kalichman 2007; Kligyte et al. 2008; McGee et al. 2008; Mitchell and Carroll 2008; Mumford et al. 2008; Wright et al. 2008; Seiler et al. 2011; Adeleye and Adebamowo 2012; Ripley et al. 2012; Rupaya 2012; Bouter 2015; Antes 2016; Antes et al. 2016; Asai, Okota, and Enzo 2016; NASEM 2017; Bion et al. 2018; ENERI 2018; Olesen et al. 2019a; Satalkar and Shaw 2019; Yi, Nemery, and Dierickx 2019; Bruton et al. 2020; Knysh et al. 2020; Mabou Tagne et al. 2020; Hofmann et al. 2020; Zeljic 2021; Abdi et al. 2021) **High awareness of the importance of research integrity and research integrity education, and knowledge of research integrity policies and procedures, good and poor research behavior, risks, and consequences of misconduct** (Institute of Medicine, National Academy of Sciences, and National Academy of Engineering 1995; DuBois 2004; Lipton, Boyd, and Bero 2004; Kalichman 2007; Jordan and Gray 2012; Vuckovic-Dekic et al. 2012; ; Foeger and Zimmerman 2015; Antes 2016; Bruton et al. 2016; Knysh et al. 2020) **Understanding the nature of ethical thinking, having knowledge on how to recognize biases in the ethical-decision process and how to handle ethical issues** (Kalichman 2007; Mumford et al. 2008; Medeiros et al. 2014; Olesen et al. 2019a)	Marušić 2018; Felaefel et al. 2018; Hoole 2019; Kretser et al. 2019; Maggio et al. 2019; Muthanna and Alduais 2020) **Lack of knowledge on research integrity, research integrity policies and procedures, good and poor research behavior, risks, and consequences of misconduct** (Fields and Price 1993; Eastwood et al. 1996; Bhopal et al. 1997; Lipton, Boyd, and Bero 2004; Dhaliwal, Singh, and Bhatia 2006; Kalichman 2006; Newman and Jones 2006; Anderson et al. 2007a; Kalichman 2007; Roland 2007; Louis et al. 2008; Mitchell and Carroll 2008; Eret and Gokmenoglu 2010; Geller et al. 2010; Nilstun, Löfmark, and Lundqvist 2010; Street et al. 2010; Horner and Minifie 2011; Adeleye and Adebamowo 2012; Amin et al. 2012; Cameron, Zhao, and McHugh 2012; Dhingra and Mishra 2014; Mahmud and Bretag 2014; Medeiros et al. 2014; Bouter 2015; Fanelli, Costas, and Larivière 2015; Foeger and Zimmerman 2015; Binder, Friedli, and Fuentes-Afflick 2016; Hofmann and Holm 2016; Ozcan and Balci 2016; Trinkle et al. 2017; Evans et al. 2018; Godecharle, Nemery, and Dierickx 2018; Maggio et al. 2019; Nathan and Shawkataly 2019; Schonhaut 2019; Yi, Nemery, and Dierickx 2019; Azakir et al. 2020; Haven et al. 2020; Hofmann et al. 2020; Knysh et al. 2020; Zeljic 2021; Li and Cornelis 2021) **Not knowing or recognizing responsibilities (lack of experience)** (Eastwood et al. 1996; Kalichman 2007; Mitchell and Carroll 2008; Medeiros et al. 2014; Fanelli, Costas, and Larivière 2015; Foeger and Zimmerman 2015; Guraya et al. 2016; Pupovac, Prijić-Samaržija, and Petrovečki 2017; Maggio et al. 2019; Azakir et al. 2020; Li and Cornelis 2021) **Different understanding of rules** (Louis et al. 2008; Nilstun, Löfmark, and Lundqvist 2010; Hofmann and Holm 2016) **Possible harmful effect of responsible conduct of research education (researchers may feel over confident in certain situations)** (Antes et al. 2010)

		Lack of English language knowledge and lack of writing skills (Eret and Gokmenoglu 2010; Cameron et al. 2012; Cui; Yue, and Kan 2015; Guraya et al. 2016; Awasthi 2019) **Improper time management** (Eret and Gokmenoglu 2010; Awasthi 2019)
Level: Research organization		
	Positive	**Negative**
Research environment and culture	**Fostering the culture of integrity, transparency, deliberation, compliance, collaboration and inclusivity** (Kalichman 2007; OECD 2007; Wright, Titus, and Cornelis 2008; Amin et al. 2012; Allen and Dowell 2013; Kalichman 2014; Bouter 2015; Israel and Drenth 2015; Korgan Hausbeck 2016; Rudin 2016; Byvaltsev et al. 2017; NASEM 2017; Olesen, Amin, and Mahadi 2017; ENERI 2018; Godecharle, Nemery, and Dierickx 2018; Malički et al. 2019; Zwart and Ter Meulen 2019; Haven et al. 2020; Abdi et al. 2021) **Good ethical climate and organizational justice** (Lombardi 1990; Institute of Medicine and National Research Council 2002; Martinson et al. 2010; Werner-Felmayer 2010; Antes 2016; Korgan Hausbeck 2016; Echols 2017; Olesen, Amin, and Mahadi 2017; DuBois and Antes 2018; ENERI 2018; Malički et al. 2019) **Creating safe and trusty environment for discussing research integrity issues** (Institute of Medicine and National Research Council 2002; OECD 2007; Geller et al. 2010; Ryan et al. 2012; Allen and Dowell 2013; Kalichman 2014; DuBois and Antes 2018; ENERI 2018; Berggren and Karabag 2019; Zwart and Ter Meulen 2019; Haven et al. 2020) **Raising awareness on research integrity and research misconduct** (Institute of Medicine and National Research Council 2002; Kalichman 2007; Steneck 2006; Vasgird 2007; Wager, Kleinert, and COPE 2012; Mahmud and Bretag 2014; Nebeker 2014; Korgan Hausbeck 2016; Rudin 2016; NASEM 2017; Olesen et al. 2018a; Awasthi 2019; Kretser et al. 2019; Malički et al. 2019) **Responding to misconduct cases** (Hilgartner 1990; Horner and Minifie	**Poor organizational climate, governance and leadership** (Roberts, Kavussanu, and Sprague 2001; Davis, Riske-Morris, and Diaz 2007; Martinson et al. 2010; Werner-Felmayer 2010; Alfredo and Hart 2011; Horner and Minifie 2011; Mahmud and Bretag 2014; Foeger and Zimmerman 2015; Antes 2016; Breit and Forsberg 2016; Echols 2017; Lombardo 2017; Pupovac, Prijić-Samaržija, and Petrovečki 2017; Trinkle et al. 2017; Bion et al. 2018; DuBois and Antes 2018; Olesen, Amin, and Mahadi 2018a; Haven et al. 2019a; Hofmann and Holm 2019; Malički et al. 2019) **Lack of positive organizational values (what organizations expect from researchers)** (Breit and Forsberg 2016; Lombardo 2017; Pupovac, Prijić-Samaržija, and Petrovečki 2017; Abedini, Imani, and Fazli 2018; Olesen, Amin, and Mahadi 2018a; Malički et al. 2019) **Focusing on profit and money, productivity and performance** (Jasanoff 1993; Roberts, Kavussanu, and Sprague 2001; Institute of Medicine and National Research Council 2002; Evans and Packham 2003; Anderson et al. 2007a; Werner-Felmayer 2010; Chen and Macfarlane 2015; Asai, Okota, and Enzo 2016; Edwards and Roy 2017; Bion et al. 2018; Ertl 2018; Aprile, Ellem, and Lole 2020; Harvey 2020; Olesen et al. 2020) **Competitiveness between academic institutions** (Institute of Medicine and National Research Council 2002; Resnik and Stewart 2014; Breit and Forsberg 2016; Guraya et al. 2016; Echols 2017; Edwards and Roy 2017; Olesen et al. 2020) **Lack of independence from industry (organizational conflict of interest)** (Douglas 1993; Jasanoff 1993; Emanuel and Steiner 1995; Cho et al. 2000; Andreopoulos 2001; Resnik and Shamoo

	2011; Wager, Kleinert, and COPE 2012; Allen and Dowell 2013; Byvaltsev et al. 2017; NASEM 2017; ENERI 2018; Abdi et al. 2021) **Promoting transparency (publishing incidence of research misconduct and other detrimental research practices; declaring conflict of interest)** (Institute of Medicine and National Research Council 2002; Evans and Packham 2003; OECD 2007; Horner and Minifie 2011; Resnik et al. 2016; Nichols-Casebolt and Macrina 2019; Resnik 2019) **Having independence from industry (e.g., not allowing funding sources to bias research results and research publications; not agreeing to any arrangements with industry that restrict the free communication of research findings and ideas)** (Evans and Packham 2003; Bruyere et al. 2010; Campbell and Zinner 2010) **The important role of research administrators in promoting research integrity (e.g., research administrators having adequate knowledge and training on research integrity, as well as having knowledge on how to handle possible research misconduct cases and provide research integrity support for researchers)** (Vasgird 2007; Korgan Hausbeck 2016; Rudin 2016) **Research leaders setting positive examples** (Institute of Medicine and National Research Council 2002; Antes 2016; Echols 2017; Martinson et al. 2017; NASEM 2017)	2002; Evans and Packham 2003; Krimsky 2003; Bruyere et al. 2010; Campbell and Zinner 2010; Liang and Mackey 2010; Resnik et al. 2016; Evans et al. 2018; Schrag 2018; Nichols-Casebolt and Macrina 2019; Resnik 2019) **Lack of organizational responsibility for misconduct of their employees** (Buljan, Barać, and Marušić 2018) **Avoiding to investigate misconduct (because of reputation)** (Douglas 1993; Rhodes and Strain 2004; Wager 2007; Resnik and Stewart 2014; Israel and Drenth 2015; Olesen et al. 2020) **Avoiding to report on misconduct investigations (because of reputation)** (Redman and Merz 2005; Israel and Drenth 2015; Olesen, Amin, and Mahadi 2018a) **Unethical behavior of organizational leaders** (Resnik and Stewart 2014; Antes 2016; Echols 2017) **Lack of attention given to research integrity issues** (Rudin 2016; Breit and Forsberg 2016; NASEM 2017; Trinkle et al. 2017; Hofmann and Holm 2019; Wang and Li 2020) **Corruption** (Akpabio and Esikot 2014; Nabaho and Turyasingura 2019)
	Positive	**Negative**
Research integrity education and support	**Providing education on different research integrity issues and for different groups of researchers (junior and senior researchers, supervisors, administrators; tailoring research integrity education to different needs)** (Hilgartner 1990; Lombardi 1990; Institute of Medicine, National Academy of Sciences, and National Academy of Engineering 1995; Lenz and Ketefian 1995; Institute of Medicine and National Research Council 2002; Motta 2002; Davis 2003; Kalichman 2006; Kalichman 2007; Mayer and Steneck 2007; OECD 2007; Roland 2007; Vasgird 2007; Mitchell and Carroll 2008; Geller et al.	**Lack of research integrity and responsible conduct of research training in the organization (or lack of effective education)** (Fields and Price 1993; Lenz and Ketefian 1995; Eastwood et al. 1996; Vijh 1996; Kalichman 2006; Macfarlane and Saitoh 2008; Antes et al. 2009; Alfredo and Hart 2011; Ryan et al. 2012; Wheeler 2015; Antes 2016; Ozcan and Balci 2016; Rudin 2016; Buljan, Barać, and Marušić 2018; Evans et al. 2018; Godecharle, Nemery, and Dierickx 2018; Haven et al. 2019a) **Lack of funds to support research integrity and responsible conduct of**

	2010; Jones et al. 2010; Street et al. 2010; Zeng and Resnik 2010; Alfredo and Hart 2011; Ripley et al. 2012; Ryan et al. 2012; Allen and Dowell 2013; Kalichman 2014; McGee et al. 2014; Resnik 2014; Resnik and Stewart 2014; Fanelli, Costas, and Larivière 2015; Gallagher 2015; Foeger and Zimmerman 2015; Vasconcelos et al. 2015; Antes 2016; Binder, Friedli, and Fuentes-Afflick 2016; Guraya et al. 2016; Korgan Hausbeck 2016; Byvaltsev et al. 2017; Echols 2017; NASEM 2017; Antes et al. 2018; Bion et al. 2018; Buljan, Barać, and Marušić 2018; Felaefel et al. 2018; Godecharle, Nemery, and Dierickx 2018; Olesen et al. 2018b; Awasthi 2019; Kretser et al. 2019; Maggio et al. 2019; Malički et al. 2019; Nichols-Casebolt and Macrina 2019; Olesen, Amin, and Mahadi 2019; Simon et al. 2019; Tessier 2019; Abbasi et al. 2020; Wang and Li 2020; Yi, Nemery, and Dierickx 2019) **Receiving feedback on provided research integrity education, updating and improving courses** (Jones et al. 2010; Kalichman 2014; Nebeker 2014; Foeger and Zimmerman 2015; Martinson et al. 2017) **Implementing research integrity training into curriculum** (NASEM 1992; Institute of Medicine and National Research Council 2002; OECD 2007; Jones et al. 2010; Dhingra and Mishra 2014; Vasconcelos et al. 2015; Yi, Nemery, and Dierickx 2019) **Providing support by developing programs for dealing with stress** (Holtfreter et al. 2020) **Educating personnel responsible for receiving complaints on research misconduct** (Lombardo 2017; Olesen et al. 2019b; Bramstedt 2021) **Establishing remedial programs for offenders** (Hoole 2019) **Providing authorship support** (Dhaliwal, Singh, and Bhatia 2006) **Establishing effective administrative support** (Vasgird 2007; Gallagher 2015; Antes 2016; Rudin 2016)	**research education** (Kalichman 2007; Korgan Hausbeck 2016) **Lack of activities for promoting research integrity** (Rudin 2016)
	Positive	**Negative**
Research integrity policies, structures and processes	**Developing, implementing, and updating research integrity policies and guidance documents for different**	**Lack of research integrity policies and guidance documents** (Nobel 1990; Fields and Price 1993; Liang and Mackey

	research integrity issues (NASEM 1992; Institute of Medicine, National Academy of Sciences, and National Academy of Engineering 1995; Boyd and Bero 2000; Andreopoulos 2001; Bird 2001; Institute of Medicine and National Research Council 2002; Anderson and Shultz 2003; Lipton, Boyd, and Bero 2004; Redman and Merz 2005; Dhaliwal, Singh, and Bhatia 2006; Mayer and Steneck 2007; OECD 2007; Macfarlane and Saitoh 2008; Nilstun, Löfmark, and Lundqvist 2010; Werner-Felmayer 2010; Alfredo and Hart 2011; Brown and Agius 2012; Masic 2012; Nichols-Casebolt 2012; Sax 2012; Mahmud and Bretag 2014; Bouter 2015; Fanelli, Costas, and Larivière 2015; Gallagher 2015; Israel and Drenth 2015; Wheeler 2015; Breit and Forsberg 2016; Resnik et al. 2016; Aubert Bonn, Godecharle, and Dierickx 2017; Byvaltsev et al. 2017; Echols 2017; Edwards and Roy 2017; Mentzelopoulos and Zakynthinos 2017; NASEM 2017; Awasthi 2019; Fanelli et al. 2019; Kretser et al. 2019; Nichols-Casebolt and Macrina 2019; Yi, Nemery, and Dierickx 2019; Mabou Tagne et al. 2020; Olesen et al. 2020) **Including researchers in the development of research integrity policies and guidance documents** (Institute of Medicine and National Research Council 2002; Mokhtarianpour, Gharamaleki, and Rajabi 2016) **Monitoring researchers' compliance with research integrity policies and guidance documents** (Lenz and Ketefian 1995; Institute of Medicine and National Research Council 2002; Anderson and Shultz 2003; Zeng and Resnik 2010; Vasconcelos et al. 2015; Bion et al. 2018; Kretser et al. 2019 **Having adequate bodies to deal with research integrity and research misconduct issues (e.g., research integrity officers and committees, ombudsman, boards for conflict of interest, bodies for ethical research and publications, management system for research integrity questions)** (National Academy of Sciences, and National Academy of Engineering and Institute of Medicine 1995; Nylenna et al. 1999;	2010; Street et al. 2010; Alfredo and Hart 2011; Akpabio and Esikot 2014; Rudin 2016; Wheeler 2015; Pupovac, Prijić-Samaržija, and Petrovečki 2017; Abbas et al. 2018; Bion et al. 2018; Buljan, Barać, and Marušić 2018; Evans et al. 2018; Wang and Li 2020; Li and Cornelis 2021) **Lack of clear, detailed and uniformed research integrity policies and guidance documents (e.g., contradictive policies; lack of congruity between national and organizational policies; lack of guidance documents tailored to the researchers' and organization's needs; differences between written guidance and real life)** (Lenz and Ketefian 1995; Eastwood et al. 1996; Cho et al. 2000; Andreopoulos 2001; Kalichman 2006; Steneck 2006; Geller et al. 2010; Nilstun, Löfmark, and Lundqvist 2010; Brown and Agius 2012; Johnsson et al. 2014; Mahmud and Bretag 2014; Foeger and Zimmerman 2015; Benko 2016; Binder, Friedli, and Fuentes-Afflick 2016; Mokhtarianpour, Gharamaleki, and Rajabi 2016; Aubert Bonn, Godecharle, and Dierickx 2017; Buljan, Barać, and Marušić 2018; Evans et al. 2018; Holtfreter et al. 2020; Olesen et al. 2020) **Lack of experts and researchers involved in the process of developing research integrity policies and guidance documents** (Mokhtarianpour, Gharamaleki, and Rajabi 2016) **Lack of developed implementation strategies for research integrity policies and guidance documents** (Nilstun, Löfmark, and Lundqvist 2010; Rudin 2016) **Lack of proper oversight (e.g.; lack of ethics and research integrity review, compliance monitoring, and functionality of different administrative bodies)** (Akpabio and Esikot 2014; Johnsson et al. 2014; Breit and Forsberg 2016; Lombardo 2017; Mentzelopoulos et al. 2017; NASEM 2017; Evans et al. 2018; Felaefel et al. 2018; Maggio et al. 2019) **Lack of effective system for dealing with allegations and misconduct cases** (Fields and Price 1993; Nilstun, Löfmark, and Lundqvist 2010; Foeger and

	Institute of Medicine and National Research Council 2002; Claxton 2005; Zeng and Resnik 2010; Ryan et al. 2012; Wager; Kleinert, and COPE 2012; Allen and Dowell 2013; Foeger and Zimmerman 2015; Israel and Drenth 2015; NASEM 2017; Buljan, Barać, and Marušić 2018; Evans et al. 2018; Resnik 2019; Yi, Nemery, and Dierickx 2019; Bramstedt 2021; Wang and Li 2020) **Developing strategies to mitigate and resolve disputes (adopting formal policies and implementing processes for addressing allegations and conducting investigations of research misconduct)** (NASEM 1992; Institute of Medicine, National Academy of Sciences, and National Academy of Engineering 1995; Lenz and Ketefian 1995; Institute of Medicine and National Research Council 2002; OECD 2007; Wager, Kleinert, and COPE 2012; Mahmud and Bretag 2014; Foeger and Zimmerman 2015; Vasconcelos et al. 2015; Benko 2016; Binder, Friedli, and Fuentes-Afflick 2016; Edwards and Roy 2017; NASEM 2017; Nabaho and Turyasingura 2019) **Implementing sanctions for research misconduct** (NASEM 1992; Institute of Medicine and National Research Council 2002; Kalichman 2007; Horner and Minifie 2011; Fanelli, Costas, and Larivière 2015; Benko 2016; Breit and Forsberg 2016; NASEM 2017; Bion et al. 2018; Nabaho and Turyasingura 2019; Olesen, Amin, and Mahadi 2019; Pratt et al. 2019; Yi, Nemery, and Dierickx 2019; Bruton et al. 2020) **Developing a program for the whistleblowers' protection** (Zeng and Resnik 2010; Allen and Dowell 2013; Resnik 2014; Gallagher 2015; Godecharle, Nemery, and Dierickx 2018; Berggren and Karabag 2019; Nabaho and Turyasingura 2019; Olesen et al. 2019b; Pratt et al. 2019; Bruton et al. 2020) **Having clearly defined roles and responsibilities for all members in the organization** (Institute of Medicine and National Research Council 2002; Redman and Merz 2005; Mahmud and Bretag 2014; Israel and Drenth 2015; Rudin 2016; NASEM 2017)	Zimmerman 2015; Echols 2017; Godecharle, Nemery, and Dierickx 2018; Holtfreter et al. 2020) **Lack of sanctions for research misconduct** (Redman and Merz 2005; Eret and Gokmenoglu 2010; Breit and Forsberg 2016; Pupovac, Prijić-Samaržija, and Petrovečki 2017; Buljan, Barać, and Marušić 2018; Holtfreter et al. 2020) **Poor accessibility to available guidance documents** (Binder, Friedli, and Fuentes-Afflick 2016) **Lack of protection for whistleblowers** (Redman and Merz 2005; Godecharle, Nemery, and Dierickx 2018; Harvey 2020)

	Developing a comprehensive plan to promote research integrity (Lenz and Ketefian 1995; National Academy of Sciences, and National Academy of Engineering 1995; Institute of Medicine, Institute of Medicine and National Research Council 2002; Steneck 2007; Wager, Klainert, and COPE 2012; Mahmud and Bretag 2014; Fanelli, Costas, and Larivière 2015; Korgan Hausbeck 2016; NASEM 2017; Godecharle, Nemery, and Dierickx 2018; Berggren and Karabag 2019) **Improving quality assurance procedures (e.g., implementing research integrity requirements in assessing the quality of research performance; intensifying routine scrutiny of research practices and research integrity compliance)** (Hilgartner 1990; Bouter 2015; NASEM 2017) **Using plagiarism software** (Masic 2012; Foeger and Zimmerman 2015; Ertl 2018; Awasthi 2019; Ayodele, Yao, and Haron 2019; Abbasi et al. 2020) **Implementing open science practices** (NASEM 2017; Hoole 2019) **Collaborating with journals in investigations of research misconduct** (Wager, Kleinert, and COPE 2012; NASEM 2017)	
Evaluations, incentives and rewards	**Positive**	**Negative**
	Putting focus on quality of research and scientific process instead of prestige, ranking and financial gain (OECD 2007; Werner-Felmayer 2010; Zeng and Resnik 2010; Guraya et al. 2016; Kretser et al. 2019; Maggio et al. 2019; Bruton et al. 2020) **Reducing publication pressure** (Mumford et al. 2007; Guraya et al. 2016; Yi, Nemery, and Dierickx 2019; Bruton et al. 2020; Abdi et al. 2021) **Evaluating and awarding research based on research integrity requirements** (Institute of Medicine and National Research Council 2002; OECD 2007; Ayodele, Yao, and Haron 2019; Kretser et al. 2019; Maggio et al. 2019; Haven et al. 2020; Wang and Li 2020)	**Performance based evaluations (e.g., performance related salaries and perverse incentives; valuing quantity of research instead the quality)** (Vijh 1996; Davis 2003; Redman and Merz 2005; Rajeshwari 2011; Cui, Yue, and Kan 2015; Edwards and Roy 2017; Mentzelopoulos et al. 2017; Hoole 2019 **Lack of recognition for researchers who follow research integrity standards in their work** (Mumford et al. 2007; Akpabio and Esikot 2014; Foeger and Zimmerman 2015; Buljan, Barać, and Marušić 2018)
Research integrity in funding organizations	**Positive**	**Negative**
	Developing and implementing policies and procedures for research integrity	**Lack of research integrity polices and monitoring procedures** (Steneck 2006)

	promotion and investigation of research misconduct (Miller et al. 2006; Evans et al. 2018; van Wee 2019) **Funding and evaluation criteria (putting more emphasis on research integrity)** (Institute of Medicine and National Research Council 2002; Miller, Moore, and Strange 2006; Steneck 2007; Kalichman 2014; Mahmud and Bretag 2014; Bouter 2015)	**Evaluations based on research topic attractiveness rather than on quality of research (output oriented funding)** (Martinson and Brian 2011; Tijdink et al. 2016b; Ertl 2018)
Level: System of science		
	Positive	**Negative**
Global research culture	**Research metrics (valuing quality over quantity)** (Hilgartner 1990; Werner-Felmayer 2010; Horner and Minifie 2011; DePellegrin and Johnston 2015; Edwards and Roy 2017; NASEM 2017; Ayodele, Yao, and Haron 2019; Kretser et al. 2019; Yi, Nemery, and Dierickx 2019) **Reducing over-competitiveness** (Jasanoff 1993; Werner-Felmayer 2010; Edwards and Roy 2017; NASEM 2017; Kretser et al. 2019; Yi, Nemery, and Dierickx 2019) **Fostering open, trustworthy, and supportive environment** (NASEM 2017; Olesen et al. 2018b; Kretser et al. 2019; Haven et al. 2020) **Harmonizing definitions of research integrity and poor research behavior (adopting common framework and vocabulary of research integrity basic concepts and definitions)** (Steneck 2006; Steneck 2007; Lombardo 2017, Olesen, Amin, and Mahadi 2019; Wang and Li 2020) **Establishing common system for dealing with research integrity and research misconduct (having national, independent bodies for research integrity training and misconduct investigations)** (Lombardi 1990; Evans and Packham 2003; Redman and Merz 2005; Kalichman 2007; Mayer and Steneck 2007; Wager 2007; Werner-Felmayer 2010; Fanelli, Costas, and Larivière 2015; Foeger and Zimmerman 2015; Israel and Drenth 2015; NASEM 2017; Liao et al. 2018; Wang and Li 2020) **Developing international databases of misconduct cases** (Awasthi 2019)	**Pressure to publish (publish or perish; research community puts too much emphasis on the number of publications and creates pressure - the number of publications is taken into account for career advancement, tenure track, research awards, obtaining funding, etc.)** (Hilgartner 1990; Bhopal et al. 1997; Davis 2003; Anderson et al. 2007a; Anderson et al. 2007b; Mayer and Steneck 2007; Fanelli 2010; Werner-Felmayer 2010; Zeng and Resnik 2010; Alfredo and Hart 2011; Horner and Minifie 2011; Amin et al. 2012; Masic 2012; Ryan et al. 2012; Van Dalen and Henkens 2012; Abdollahi, Gasparyan, and Saeidnia 2014; Bouter 2015; Cui, Yue, and Kan 2015; DePellegrin and Johnston 2015; Fanelli, Costas, and Larivière 2015; Gallagher 2015; Foeger and Zimmerman 2015; Guraya et al. 2016; Echols 2017; Gasparyan et al. 2017; Trinkle et al. 2017; Abbas et al. 2018; Buljan, Barać, and Marušić 2018; Godecharle, Nemery, and Dierickx 2018; Schrag 2018; Asman et al. 2019; Fanelli et al. 2019; Hoole 2019; Maggio et al. 2019; Nathan and Shawkataly 2019; Satalkar and Shaw 2019; Abbasi et al. 2020; Bruton et al. 2020; Harvey 2020; Mabou Tagne et al. 2020; Abdi et al. 2021; Li and Cornelis 2021) **Impact factor mania (judging the value of research merely based on the impact factor of the journal in which research is published; research community putting too much emphasis on impact factors when evaluating research for career advancement, awards, and funding opportunities)** (Abdollahi et al. 2014; DePellegrin and Johnston 2015;

	Professional societies developing training programs and activities for research integrity promotion (Jones 2003; Newman and Jones 2006; Macrina 2007; NASEM 2017; Kretser et al. 2019; Knysh et al. 2020)	Edwards and Roy 2017; Gasparyan et al. 2017; Abbas et al. 2018; Haven et al. 2020) **Focus on competition and productivity (incentive system based on number of publications and impact factors; institutional ranking based on productivity)** (Lombardi 1990; Jasanoff 1993; Anderson et al. 2007b; Mayer and Steneck 2007; Macfarlane and Saitoh 2008; Fanelli 2010; Zeng and Resnik 2010; Martinson and Brian 2011; Rajeshwari 2011; Amin et al. 2012; Van Dalen and Henkens 2012; Tijdink et al. 2014; Chen and Macfarlane 2015; Cui, Yue, and Kan 2015; Asai et al. 2016; Benko 2016; Binder, Friedli, and Fuentes-Afflick 2016; Tijdink et al. 2016b; Aubert Bonn, Godecharle, and Dierickx 2017; Edwards and Roy 2017; Gasparyan et al. 2017; Antes et al. 2018; Ertl 2018; Evans et al. 2018; Felaefel et al. 2018; Liao et al. 2018; Olesen, Amin, and Mahadi 2018b; Ayodele, Yao, and Haron 2019; Fanelli et al. 2019; Nathan and Shawkataly 2019; Bruton et al. 2020; Abdi et al. 2021; Li and Cornelis 2021) **Commercialization of research (e.g., emphasizing research collaborations with industry for increasing funding opportunities, financial gain, and success which may pose challenges for research integrity (conflict of interest and commercial pressure)** (Krimsky 2003; Benko 2016; Breit and Forsberg 2016; Godecharle, Nemery, and Dierickx 2018; Schrag 2018; Harvey 2020) **Prioritizing economic growth over policy and regulation related to research** (Olesen, Amin, and Mahadi 2017; Liao et al. 2018; Schrag 2018) **Corruption** (Chen and Macfarlane 2015; Evans et al. 2018) **Differences between countries and disciplinary fields in defining poor research behavior (e.g., lack of harmonization on research integrity concepts, policies and procedures; in some countries cheating is more acceptable or different level of emphasis is given to different research integrity issues)** (Hilgartner 1990; Fields and Price 1993; Jasanoff 1993; Institute of Medicine, National Academy of

		Sciences, and National Academy of Engineering 1995; Lenz and Ketefian 1995; Nylenna et al. 1999; Davis 2003; Cribb 2004; Claxton 2005; Steneck 2006; Mayer and Steneck 2007; Louis et al. 2008; Macfarlane and Saitoh 2008; Street et al. 2010; Fanelli 2011; Amin et al. 2012; Cameron et al. 2012; Godecharle, Nemery, and Dierickx 2014; Foeger and Zimmerman 2015; Vasconcelos et al. 2015; Wheeler 2015; Benko 2016; Gasparyan et al. 2017; Lombardo 2017; NASEM 2017; Antes et al. 2018; Buljan, Barać, and Marušić 2018; ENERI 2018; Ertl 2018; Evans et al. 2018; Felaefel et al. 2018; Godecharle, Nemery, and Dierickx 2018; Liao et al. 2018; Olesen et al. 2019b; Shaw 2019; Mabou Tagne et al. 2020) **Lack of research integrity culture in community** (Marušić, Katavić, and Marušić 2007; Breit and Forsberg 2016) **PhD centric understanding of research (e.g., for pursuing an academic career, obtaining research projects, funds, and achieving other benefits, obtaining the PhD is an important factor – may lead to researchers doing research only to obtain a degree rather than seriously pursue the new knowledge)** (Rajeshwari 2011) **Focusing only on fabrication, falsification, and plagiarism (less attention given to other detrimental research practices)** (Martinson, Anderson, and De Vries 2005; Knysh et al. 2020)
Scientific journals and publishers	**Positive**	**Negative**
	Having defined policies and procedures for research integrity issues (Evans and Packham 2003; Krimsky 2003; Marušić, Katavić, and Marušić 2007; Mayer and Steneck 2007; Bauchner and Fontanarosa 2012; NASEM 2017) **Improving peer review process (e.g., journals and publishers implementing ethical and research integrity policies for peer reviewers; having clear policies on roles and responsibilities of reviewers; implementing policies outlining procedures that should be followed when peer reviewer notices misconduct in research publications;**	**Lack of enthusiasm to publish negative research results** (Fanelli 2010; Gasparyan et al. 2017; Buljan, Barać, and Marušić 2018; Harvey 2020; Li and Cornelis 2021) **Corruption** (Marušić 2010) **Not retracting or correcting articles (or doing it silently)** (Teixeira da Silva 2016) **Editors (volunteer position; lack of training; not willing to involve in research misconduct investigations and sanctions)** (Marušić, Katavić, and Marušić 2007; Marušić 2010)

	journals negotiating transparently and honestly in author-reviewer disputes) (NASEM 2017; Bruton et al. 2020; Abdi et al. 2021) **Publishing negative research results** (Evans et al. 2018; Kretser et al. 2019; Bruton et al. 2020) **Promoting open science** (NASEM 2017; Evans et al. 2018; Bruton et al. 2020) **Implementing practices for research misconduct (e.g., retracting fraudulent publications, informing research organizations about suspected misconduct, cooperating with research organizations in investigations)** (Mayer and Steneck 2007; Wager 2007; Horner and Minifie 2011; Bauchner and Fontanarosa 2012; Wager, Kleinert, and COPE 2012; Fanelli, Costas, and Larivière 2015; Guraya et al. 2016; NASEM 2017; Ayodele, Yao, and Haron 2019; Schonhaut 2019) **Awareness raising activities (e.g., having special sections on research integrity issues)** (Yi, Nemery, and Dierickx 2019) **The role of editors (educators of research integrity)** (Marušić, Katavić, and Marušić 2007; Wager 2007; Marušić 2010) **Publishing rejection rates and informing researchers about the quality of published research** (ENERI 2018)	

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APPENDIX 10: Critical appraisal of evidence for quasi-experimental studies (Tufanaru et al. 2020), randomized controlled trials (Tufanaru et al. 2020), and qualitative study (Lockwood, Munn, and Porritt 2015)

Quasi-experimental studies (Tufanaru et al. 2020)	
Item	**Decision and description**
1. Is it clear in the study what is the 'cause' and what is the 'effect' (i.e. there is no confusion about which variable comes first)?	Powell, Allison, and Kalichman 2007; Kligyte et al. 2008; Mumford et al. 2008; Antes et al. 2010; Gray and Jordan 2012; Jordan and Gray 2012; Mabou Tagne et al. 2020: Yes. It is clearly stated what the study aim , intervention, and outcome of interest was
2.Where the participants included in any comparison similar?	Powell, Allison, and Kalichman 2007; Kligyte et al. 2008; Antes et al. 2010; Gray and Jordan 2012; Jordan and Gray 2012; Mabou Tagne et al. 2020: Yes. Same group; pre-and-post-test study. Mumford et al. 2008: Yes. Same group; pre-and-post-test study. There was a control group, but the comparison was not performed.
3. Were the participants included in any comparisons receiving similar treatment/care, other than the exposure or intervention of interest?	Powell, Allison, and Kalichman 2007: Unclear. The possibility of participants being exposed to other external factors unrelated to study and intervention was reported (other education and training). Kligyte et al. 2008: Unclear. It is not explicitly stated whether participants were exposed to some other intentional or unintentional treatments or factors co-occurring with intervention. The authors stated that the study included participants in a multi-disciplinary center that involves researchers from different universities; hence there was a possibility that participants were under the influence of the research climate or culture predominant in their university. Mumford et al. 2008: Unclear. The possibility of participants completing pre-and-post measure being exposed to other, external factors, not related to study and intervention was reported. It is reported that results on training effectiveness might be influenced by professional expertise, personality traits, or the voluntary nature of participating in the study. Also, the participants were offered an incentive for testing and retesting in the follow-up. There was no comparison of results between the experimental and control group. Antes et al. 2010: Unclear. It is not explicitly stated whether participants were exposed to some other intentional or unintentional treatments or factors co-occurring with the intervention. The authors mention several limitations that might affect the results: voluntary nature of participation in the study, lack of control over the test-taking environment, and factors such as poor mentoring or observation of misconduct. Gray and Jordan 2012; Jordan and Gray 2012; Mabou Tagne et al. 2020: Unclear. It is not explicitly stated whether participants

	were exposed to some other intentional or unintentional treatments or factors co-occurring with the intervention.
4. Was there a control group?	Powell, Allison, and Kalichman 2007; Kligyte et al. 2008; Antes et al. 2010; Gray and Jordan 2012; Jordan and Gray 2012; Mabou Tagne et al. 2020: No. There was no control group reported in the study. Mumford et al. 2008: Yes. A separate sample of 245 doctoral students who did not receive training was used as a control group. There was no comparison between the experimental and control group.
5. Were there multiple measurements of the outcome both pre and post the intervention/exposure?	Powell, Allison, and Kalichman 2007: No. The measurements were collected once pre-exposure and once post-exposure. Additionally, for two groups, the data were collected only after the intervention. Kligyte et al. 2008; Antes et al. 2010; Gray and Jordan 2012; Jordan and Gray 2012; Mabou Tagne et al. 2020: No. The measurements were collected once pre-exposure and once post-exposure. There were no multiple pre-test and post-test measurements. Mumford et al. 2008: Yes. The experimental group was tested once more after the post-test.
6. Was follow up complete and if not, were differences between groups in terms of their follow-up adequately described and analyzed?	Powell, Allison, and Kalichman 2007: No. The post-test was not completed; however, some descriptions, explanations, and analyses of differences were provided. One post-test only measuring was conducted in 2001 (13/29 students who participated in the course completed the post-test). One post-test only measuring was conducted in 2002 (14/36 students who participated in the course completed the post-test). In 2003 23/23 students who participated in the course completed the pre-test, and 15/16 students participated in the post-test. Some data about participants' characteristics were presented (experience with previous research ethics courses and years of research experience). No significant differences were found between groups of students. Kligyte et al. 2008: No. The follow-up was not completed; however, the characteristics of the participants were presented. The total sample consisted of 42 participants, however, only 29 participants completed both pre-and-post-tests due to time constraints and working schedule. The data of participants who completed only pre or post-test were not included in the final analysis. No significant differences were found between participants who completed both pre-and-post-test and those who completed only pre or post-test (independent samples t-test was performed). Mumford et al. 2008: The post-test, conducted immediately after the training was completed and the follow-up (second post-test six months after the intervention) was not completed. The sample consisted of 59 participants (general characteristics of the participants were reported). 18/59 participants completed the

	follow-up. There were no explanations for the loss and analysis of the participants' characteristics and the impact of the loss. Antes et al. 2010: No. The post-test was not completed. The sample consisted of 53 participants who completed both pre-and-post-test. Participants who only completed pre-test (n=86) or post-test (n=34) were compared with the participants who completed both to identify systematic differences between groups. No differences were found. Gray and Jordan 2012: No. The post-test was not completed. 1002/1280 students completed the survey (549 pre-test and 453 post-test). The differences between participants and any analysis of participants' characteristics and the impact of the loss were not reported. Jordan and Gray 2012: No. The post-test was not completed. Narrative reasons for the loss are briefly provided (attendance requirements; students were required to attend 4/6 lectures and may have skipped the final lecture when the post-test was administrated), and differences between groups are presented (demographic data for pre-test, post-test, and overall); however, the analysis of the loss and its impact was not presented. 549 students completed the pre-test, and 453 students completed the post-test. Mabou Tagne et al. 2020: No. The post-test was not completed, and differences between groups were not presented. 46/65 participants completed the post-test.
7. Were the outcomes of participants included in any comparisons measured in the same way?	Powell, Allison, and Kalichman 2007: Yes. The same measuring instrument was used (Research Ethics Survey). Kligyte et al. 2008; Mumford et al. 2008: No. The scenarios for ethical decision measures (EDM) were different for pre-and-post-test assessment. Antes et al. 2010: Unclear. It seems like the outcomes were measured in the same way; however, other studies from the same group used different pre-and-post- instrument (the same instrument but different questions). Gray and Jordan 2012; Jordan and Gray 2012: Yes. Pre and post-measure were the same (30-question survey). Mabou Tagne et al. 2020: Yes. The same instrument was used (SMQ-R).
8. Were outcomes measured in reliable way?	Powell, Allison, and Kalichman 2007: Yes. The instrument was developed based only on the preliminary findings of another at that time ongoing study. Kligyte et al. 2008; Mumford et al. 2008; Antes et al. 2010; Mabou Tagne et al. 2020: Yes. It was validated in the previous study.

	Gray and Jordan 2012; Jordan and Gray 2012: Unclear. The survey was only validated for question clarity and time to completion.
9. Was the appropriate statistical analysis used?	Powell, Allison, and Kalichman 2007; Mumford et al. 2008; Gray and Jordan 2012; Jordan and Gray 2012; Mabou Tagne et al. 2020: Yes. Appropriate statistical tests were used. Kligyte et al. 2008; Antes et al 2010: Unclear. Analysis of variance was used, but it was not stated whether the data followed a normal distribution.
Additional criterion: Who created the intevention, who delivered it and who analyzed the data?	Powell, Allison, and Kalichman 2007: Not stated. Three authors performed scoring. Kligyte et al. 2008: Unclear. It seems that the researchers developed the intervention and delivered it, and collected and analyzed the data. Mumford et al. 2008: Unclear. Separate senior trainers provided the intervention. Antes et al. 2010: The intervention was RCR course at different institutions, created by the RCR instructors, who also gave the course. The study questionnaire was online, and the researchers who created the measure also analyzed the data. Gray and Jordan 2012; Jordan and Gray 2012: The researcher who analyzed the data and created the survey did not deliver the intervention and did not collect data (a teaching assistant distributed and collected surveys in the class). Mabou Tagne et al. 2020: Unclear, i.e., not stated.
Randomized Controlled Trials (Tufanaru et al. 2020)	
Item	**Decision and description**
1.Was true randomization used for assignment of participants to treatment groups?	Martinson et al. 2017: Yes. Veterans Health Administration facilities were randomly selected. Facilities were divided into three groups, and from each group facilities were sampled in equal proportions. Bruton et al. 2020: Yes. A list of available email addresses was assembled to create a list of potential participants. Participants were selected randomly from the list.
2. Was allocation to treatment groups concealed?	Martinson et al. 2017; Bruton et al. 2020: Unclear. Not stated.
3. Were treatment groups similar at the baseline?	Martinson et al. 2017; Bruton et al. 2020: Unclear. Not presented.
5. Were those delivering treatment blind to treatment assignment?	Martinson et al. 2017; Bruton et al. 2020: Unclear. Not stated (probably not).
6. Were outcomes assessors blind to treatment assignment?	Martinson et al. 2017: Yes. Two team members that coded the data did not know about the study arm assignment. All team members, except the statistician, were blinded about the ranking of facilities by their receptivity to quality improvement feedback. Bruton et al. 2020: Unclear. Not stated.

7. Were treatment groups treated identically other than the intervention of interest?	Martinson et al. 2017; Bruton et al. 2020: Unclear. Not stated.
8. Was follow up complete and if not, were differences between groups in terms of their follow up adequately described and analyzed?	Martinson et al. 2017: No. Follow-up was not completed. Research service leaders from 25 facilities accepted the participation in the study. One participant dropped out because of the inadequate return of the survey. 21 participants completed the follow-up interviews. Bruton et al. 2020: No. The follow-up was not complete. 287 participants answered the Likert-style questions, and 255 participants provided narrative responses.
9. Were participants analyzed in the groups to which they were randomized?	Martinson et al. 2017; Bruton et al. 2020: Yes. The participants were analyzed in the groups to which they were initially randomized.
10. Were outcomes measured in the same way for treatment groups?	Martinson et al. 2017: Yes. The outcomes were measured the same way; the same instrument was used (Survey of Organizational Research Climates). Bruton et al. 2020: Yes. The outcomes were measured the same way; the same instrument was used (31 Likert-type questions survey).
11. Were outcomes measured in a reliable way?	Martinson et al. 2017: Yes. It was validated in previous studies. Bruton et al. 2020: Unclear. Not stated.
12. Was appropriate statistical analysis used?	Martinson et al. 2017; Bruton et al. 2020: Yes. Appropriate statistical tests were used
13. Was the trial design appropriate, and any deviations from the standard RCT design (individual randomization, parallel groups) accounted for in the conduct and analysis of the trial?	Martinson et al. 2017; Bruton et al. 2020: Yes. The trial design was appropriate for the topic.
Qualitative study (Lockwood, Munn, and Porritt 2015)	
Item	**Decision and description**
1. Is there congruity between the stated philosophical perspective and the research methodology?	Seiler et al. 2011: Yes. The authors stated several presumptions about role-play scenarios and case discussions used in the RCR training (based on previous research). They intended to explore attitudes and experiences more in-depth.
2. Is there congruity between the research methodology and the research question or objectives?	Seiler et al. 2011: Yes. The authors stated the interest in exploring participants' attitudes, experiences and obtained RCR knowledge related to role-play training and case discussions. For exploring these, individual interviews were conducted.
3. Is there congruity between the research methodology and the methods used to collect data?	Seiler et al. 2011: Yes. The study used appropriate methods (qualitative interviews).
4. Is there congruity between the research methodology and the representation and analysis of data?	Seiler et al. 2011: Yes. The data were presented and analyzed in accordance with the research methodology.
5. Is there congruity between the research methodology and the interpretation of results?	Seiler et al. 2011: Yes. The interpretation of the results was in accordance with the methodology.
6. Is there a statement locating the researcher culturally or theoretically?	Seiler et al. 2011: No. There is no statement about locating researchers culturally or theoretically.
7. Is the influence of the researcher on the research, and vice-versa, addressed?	Seiler et al. 2011: No. The influence of researchers on the research was not reported.
8. Are participants, and their voices, adequately represented?	Seiler et al. 2011: Yes. The participants, their characteristics, and results were adequately presented.

9. Is the research ethical according to current criteria or, for recent studies, and is there evidence of ethical approval by an appropriate body?	Seiler et al. 2011: Yes. The research was ethical and obtained approval from the local Institutional Review Board.
10. Do the conclusions drawn in the research report flow from the analysis, or interpretation, of the data?	Seiler et al. 2011: Yes. Conclusions were based on the presented data.

APPENDIX 11: Quotes supporting the themes and sub-themes

Theme 1: Divergence in knowledge and perceptions about SOPs as type of RI guidance documents	
Different understanding and lack of SOPs for RI promotion	***Examples of SOPs:*** *P2: Well I guess the first one, the basic one is the ALLEA code.* *P17: Well, what I sometimes use is the EQUATOR Network. […] So there are a lot of reporting guidelines connected, so it's not just one standard operating procedures that is there, but it's a collection.* *P19: I think the most common SOP that we are using and beginning to require are EQUATOR Network reporting guidelines for specific study types.* *P3: I guess one other area that I'm familiar with, where there is something that you might consider of sufficient detail to be an SOP, and that is in the preparation of images for submission to journals.* ***Knowledge of SOPs:*** *P12: I do not know of any SOPs or procedures that are called standard operating procedures in that field. I know of SOPs in my research field, like … in epidemiology when you do a survey, you have standard operating procedures, if you take samples you have SOPs and that is a protocol with the detailed spelling out of what you should do and how you should do it. So, I am not aware of SOPs in the field of RI.* *P10: No, frankly … I am, myself not aware of existing SOPs pertaining to research integrity. I have to admit that.* *P3: I am not aware of anything that you would call an SOP. They tend to be much more high level guidelines very, you know, by which I mean quite vague, quite general and I'm thinking about things like the Singapore statement which would, you know, that would be a sort of a good example of a high level aspirational guideline.*

Differing perceptions on the impact of SOPs on RI promotion	***The need for SOPs:*** *P8: I really think that the standard, at least for the scientists, I really think that they need the standard operating procedures. […] And that I think the SOPs could really help, help them to have a more scientific focus or approach to research integrity and research ethics issues.* *P22: Standardizing all kinds of procedures is very, very helpful for those who have to work with it and do the work because they hardly have a grip on, on all kinds of processes. So the better is written out, the bigger the chances that it will prevent sloppy science […].* ***Scepticism towards SOPs for RI:*** *P3: […] As I said, I think they're useful for the technical things or the things that people genuinely didn't know were a problem. I don't really believe though the SOPs can have much influence on culture.* *P12: So, culture, if you have a culture of looking for innovation, for creative, maybe it will be less likely to have very strict standard procedures […].* *P2: But I think where it becomes a little bit tricky is … it's easier to look at it when it's the sciences. Meaning life science, health science, even social sciences. It's easier to pick up. But when you're looking at other things like the creative arts and music, and people who do music research and conservatories type of stuff, that's a lot harder.* *P12: In RPOs [Research Performing Organizations] you have to have SOPs for operating piece of equipment, for handling animals and so on, but that is very practical. I mean, it is sort of recipe on how you work, and that will be beneficial for RI. But in RFOs [Research Funding Organizations] I do not know how you could have very strict SOPs. You can have guidelines, recommendations, you could check. I do not think SOPs can be implemented in RFOs.*

Theme 2: Barriers and facilitators related to the successful implementation of RI guidance documents and RI practices	
Research culture, bureaucracy, and individual motivations as barriers for implementation	***RI challenges, existing differences, and external factors:*** *P17: Yeah, and I think that that's really a challenge for the research integrity. Because research is a global thing but the culture is so different across the world. So that it's very difficult for research integrity because you want the same rules to apply to all of us because the … yeah, because research is a global, a global endeavor.* *P9: Philosophy of science is a very different research culture than an applied ethics. […] yeah those are two different, very different research cultures.* *P2: […] And so, when you have people writing SOPs about what is research misconduct, at the base line there's not even agreement on what research misconduct is.* *P11: The definition given by the US is not the same definition that we use in Europe for example. […] The European Code of Conduct tried to put a definition but if you look at the Danish code and the ALLEA [All European Academies] code it's not the same definition. […] So at the European level, we have some difficulties to understand how we could harmonize.* *P12: Well, I can tell you one thing. There's still not a harmonization on even the definition of research misconduct. And so, when you have people writing SOPs about what is research misconduct, at the base line there's not even agreement on what research misconduct is.* *P5: So I think currently the main negative impact on the research cultures is the publish or perish situation […].* *P18: In academia in particular I think there are a lot of pressures. Pressure to publish, pressure to get in funding, pressure to, actually supervise lots, lots of students.* *P3: I mean if there were no rewards for publishing, for example if you are never measured by your publications and*

	publications didn't carry any reward then I don't think we would ever have a problem, say, with predatory journals, we wouldn't have a problem with authorship, we wouldn't have problems with plagiarism. The whole thing would go away. So it really depends on the incentives and if you put too big an incentive to publish then yes that's when you start to get the problems with all those things I just mentioned. ***Internal factors:*** *P1: So … most generally, besides ignorance that I've mentioned before, serious misconduct is, I guess, always related to some kind of personal gain […]. Some kind of gain whether it's a, it's fame or money or, you know, promotion or … That, that would be I guess main reasons that I can imagine somebody would decide to, to engage in misconduct.* *P19: I think motivations often are two sided. And so, you want to believe, we want to believe that researchers are inherently honest and motivated for altruistic reasons. That's we all want to believe at. But then along the way there are motivations that can counter that altruism. Various forms of bias. The desire for success. Can sometimes turn into the desire for positive results. And then the desire for additional funding and grants.* ***Administrative burden:*** *P4: […] Ethical considerations are always secondary. Cause that, that's not their interest. That's just something that they need to consider and sometimes, sometimes do something about it in order to focus or work … […] Probably minimum effort that you need to spend and that you spent on that. And then, and then just, you know, yeah, you tick that box, yeah. It's done, you've done it. It's ethically okay and so on. So for the majority of cases, I think, that's the approach.* *P5: One of the issues with procedures is that they look like administrative burden for most of the, of the researchers. […] Another major issue is that, I think is, that a lot of researchers will consider that, all these procedures are going to reduce their innovation, the capacity for innovation. It will be a barrier to having new ideas […].*

Adjusting RI guidance documents and practices to researchers' needs	*P4: […] I think that a crucial point is whether, whether the users of this SOPs find them relevant for them. […] So you can come up with beautiful SOPs but if users don't find them relevant or perhaps don't need, don't feel they need them, then I don't think you'll … you'll reap much success with that. […] So it's, it needs to be based in practice and practical experience. So, that's, I think one of the important element or feature of the SOP. So that it's as close to the real experience of someone who is doing that procedure as possible.* *P14: […] in short, give concrete application to these principles taking into account that precisely, that maybe we can't make an application the same for everyone, but it will have to be articulated according to different contexts.* *P16: […] I think every subject field should have and has its own standards because the topic, the subject of the research is so, or the object of the research, is so different. So yeah, I think it should be done per research field.*
Successful implementation of RI guidance documents and practices through education	*P2: If you gonna require people to adhere to them, you have to train people to them. So you need to set up a training plan, so everybody knows, knows about them, knows how to find them and knows the content and understands the content of those SOPs.* *P15: I think that the biggest thing is raising awareness and education, you know. […] I can't say this strongly enough, you have to raise awareness and then you have to teach people how to do things properly […].* *P17: Because I think if researchers better understand why they have to do it in a certain way, then they don't feel like it's, it's another rule, it's another bureaucracy thing. But they, if they understand why they have to do it that way they are also more likely to do it the right way right away.* *P19: I think education for responsible conduct of research is key.*

	Tailored education: *P1: So, early stage researchers are educated by their mentors but then mentors also need to get educated in about how to mentor […].* *P19: But I think it probably has to be tailored. And as you mature in your research career it needs to be tailored. I do agree that a version of RCR [Responsible Conduct of Research] training is needed at all levels.* *P18: I think, I think they should actively, hold mandatory training sessions. So for example it could be a part of the on boarding. So when you've joined the research institution it should probably be a mandatory thing that right, as a researcher regardless of what you're studying you need to learn about these basic principles of ethical research. And then there might be more specific things.* *P1: […] and probably the best way to do it is through real life cases because they engage people and sometime, you know, when you hear about all those crazy things that people have done, that can interest students and then you can start from there, you can start having the discussion and, you know, helping them understand why it's important.* *P2: And we try to teach one concept where somebody might do a one-hour lecture, we'll teach it in three minutes. With fun music and in a fun way and we try to show the plus side, yeah. Otherwise it's like rules and you're hitting them over the head and you're the police and they just will, they'll not engage with you.* *P20: […] So I would like to engage with people like more individually so to provide more like targeted advice and guide them and maybe explain more what could go wrong if they don't go this way.*

Theme 3: Enhancing the RI promotion and implementation – necessary changes and steps toward improvements

General and detailed guidance:

P19: I think that codes that are general are needed. Cause they're foundational and they have the principles. But they don't have the steps. And I think you need the foundation and then the actual steps. And hopefully they don't contradict.

P1: I would say that there should be a general code of conduct that should at least have the main points explicit and then maybe direct readers to different documents.

SOPs for funders:
P20: So I think that maybe some SOPs for the small funders will be something you might need to consider.

P12: There should be SOPs when people apply for funding or there should be SOPs when you assess application […].

P12: […] but in RFOs I do not know how you could have very strict SOPs. You can have guidelines, recommendations, you could check … I do not think SOPs … can be implemented in RFOs

Including researchers in the process of developing guidance documents:
P2: I think that if it's well known from the start, that the researchers themselves are actually involved in writing them, that will send a positive message to the institution that these just didn't come from the dean or the rector and we're throwing these on you. So I think that's a really good place to start. […] You've gotta have some scientists involved on the team but you also have to have professional, true ethicists. […] So, I think those are key players in building documents, whether it's a code of ethics or SOP.

P4: And there's perhaps another thing and that is, that it may be good and useful to include and engage the researchers in the creation of SOPs themselves. […] So that they can feel, feel that they contributed to developing that and that they can ensure that it's, that they're developed in a way that is relevant for them.

Institutional support:
P14: There must be institutional support because without staff or without funding, we reach a certain point of implementation. So, there must be support at an institutional and formal level of recognition, but this is not enough if there is not a strong personal motivation and therefore the two aspects must always be together because one supports the other.

P4: At central level organizations or bodies can perhaps facilitate, provide some support for that, encourage that, provide, I don't know, perhaps special expert teams to help with this process, or some funding if possible.

P19: In many institutions there is a research integrity officer. Who hopefully has control over that. And can help assess if there're inconsistencies in guidance or SOPs.

Incentives:
P23: And personally I think that institutions by only setting a few examples can already make a huge difference. They only award with the few examples and say hey we, we promote or we make this person a professor because he or she has excellent work in doing research in responsible way and … yeah, promoting responsible and reproducible research.

P8: […] I think probably the most important thing is start to change the way you evaluate the scientists. At least to give a sign that quantity is not all.

P18: […] As researchers, yes, it's your duty to publish but it shouldn't be your duty to publish in high impact factor journals. […] So I think the incentive shipped from the institution should be publish a good quality research.

What can funders do:
P23: The funder has the money. So the funder can force things by putting money or refusing to pay money.

P18: I think maybe with funders they could do more to follow up. So that the outcome of the funding isn't just this publication at the end or two or three publications at the end.

P11: […] for sure they have an impact in the sense that they could force the applicant and as well as the institution, submitting to get funding just to have something.

What can scientific journals do:
P18: […] I think there are different views on how much responsibility the publisher has. Some publishers will say oh you know it's, it's up to the authors and the research community. But I think we now have enough examples to be honest to go no, we definitely need to sit up and to take some responsibility ourselves. […] So from the publisher's side the main thing we can do is retract and answer them. And when we're retracting we also have to be clear why are we retracting.

P19: […] Then a journal has a responsibility to retract that article and to make that public. And to make that retraction public. Not behind a paywall. And to make sure that the retracted

article is properly labelled and watermarked do not use. And so that's where journals can help make that public.