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What's next for responsible artificial intelligence: a way forward through responsible innovation

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ABSTRACT

Industry is adopting artificial intelligence (AI) at a rapid pace and a growing number of countries have declared national AI strategies. However, several spectacular AI failures have led to ethical concerns about responsibility in AI development and use, which gave rise to the emerging field of responsible AI (RAI). The field of responsible innovation (RI) has a longer history and evolved toward a framework for the entire research, development, and innovation life cycle. However, this research demonstrates that the uptake of RI by RAI has been slow. RAI has been developing independently, with three times the number of publications than RI. The objective and knowledge contribution of this research was to understand how RAI has been developing independently from RI and contribute to how RI could be leveraged toward the progression of RAI in a causal loop diagram. It is concluded that stakeholder engagement of citizens from diverse cultures across the Global North and South is a policy leverage point for moving the RI adoption by RAI toward global best practice. A role-specific recommendation for policy makers is made to deploy modes of engaging with the Global South with more urgency to avoid the risk of harming vulnerable populations. As an additional methodological contribution, this study employs a novel method, systematic science mapping, which combines systematic literature reviews with science mapping. This new method enabled the discovery of an emerging 'axis of adoption' of RI by RAI around the thematic areas of ethics, governance, stakeholder engagement, and sustainability. 828 Scopus articles were mapped for RI and 2489 articles were mapped for RAI. The research presented here is by any measure the largest systematic literature review of both fields to date and the only cross-disciplinary review from a methodological perspective.

1. Introduction

The atom bombs of the last century, the contribution of 'innovative' financial products to the culmination of the global financial crisis in 2008, or wrongful arrests caused by facial recognition technology are examples of innovations with harmful consequences [1–3]. In response to the unintended negative consequences of innovations, the responsible innovation (RI) movement has gained traction in its endeavors to balance economic, environmental, and sociocultural interests [4]. RI is often also referred to as 'responsible research and innovation (RRI)' in Europe or 'responsible development' in a nanotechnology context [5–8]. It will be discussed in Section 2.1 (Administrative and Industry Discourses of Responsible Innovation) that RRI emerged mainly from a government-driven policy discourse [9]. Industry uses the term RI more widely than the other terms [3]. The acronym 'RI' is used throughout this research and includes the stages of research and development at the front end of innovation.

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RI concepts have a history of debate mainly in nanotechnology, genetics, synthetic biology, agritech, and geoengineering [10,11]. More recently, RI is taking center stage in the convergence of nanotechnology, biotechnology, information technology, and cognitive science, known as 'NBIC' [6,12,13].

Artificial intelligence (AI) is a multidisciplinary field to create autonomous machines (i.e., robots) or train computer software to behave rationally and humanly [14,15]. AI lies at the heart of the fourth industrial revolution [16], which takes innovation in automation, robotics, and cloud computing to a new generation of smart factories, autonomous systems, and the internet of things [17]. In such industry applications, AI is increasingly being combined with other innovations, such as distributed ledger technology (e.g., blockchain), quantum computing, and extended reality [18]. These innovation combinations are often referred to as 'smart' technologies. For example, when technology innovations in the financial services sector combine AI with blockchain, extended reality, or robotic process automation, they are referred to as 'smart fintech' [19].

First, this Introduction section discusses administrative, industry, and academic discourses of RI. Next, AI is presented through an academic lense of RI to establish the importance of AI as perceived by the literature on RI. Then, a case is made for why the field of RAI should reciprocate and embrace RI. Next, it is exposed that the academic field of RAI does not reciprocate its relevance to RI, despite RI's earlier foundations. Then, the objective and contribution of this research are presented with specific research questions to understand how RAI has been developing independently from RI, and how to reverse this trend toward leveraging RI for RAI advancement.

1.1. *Artificial intelligence through a lens of responsible innovation*

A Scopus database search for 'responsible innovation', 'responsible research and innovation', and 'responsible development' in the titles, abstracts, and keywords found 1429 publications in the period 1976–2020. Fig. 1 shows an excerpt of a bibliometric map for these publications, which was obtained with the VOSviewer tool.

A shorter distance between two RI concepts in Fig. 1 reflects a stronger relationship [20]. The size of a sphere reflects its 'centrality' (i.e., influence) in the corpus [21]. The thickness of connecting lines denotes the relative strength of linked concepts [22].

The concentric circle in Fig. 1 zooms in around RI. It can be seen that AI has become a technology focus for RI in academia ahead of nanotechnology. The European Union (EU) recognized that RI provides a suitable framework for building public trust [23,24] and became the first government globally to release draft regulations for the development and use of 'trustworthy AI', based on RI principles [25].[1] The EU's Horizon 2020 program for funding research and innovation in the period 2014–2020, including its AI projects, therefore, resides within this 'inner circle'. For example, Horizon's Human Brain Project develops novel information and communication technology (ICT) architectures, based on convergence with neuroscience, and integrated governance for ethical and social issues [26]. Alternative terms often used for 'trustworthy AI' are 'responsible AI (RAI)', 'beneficial AI', or 'ethical AI' [24,27–30]. The term RAI is used in the remainder of this research.

1.2. *Why artificial intelligence should embrace responsible innovation*

This section discusses some spectacular AI failures in the wake of its compound aggregate growth rate above 35% until 2026 in industry and an emerging innovations race at a geopolitical level to claim leadership in at least some aspects of the technology [31–35].

The People's Republic of China (PRC) is promoting AI policies with weak privacy regulations, which enables it to harvest data from its large population (and arguably, the TikTok app) for leadership in image and speech recognition algorithms [32,36–38]. In the US conversely, facial recognition algorithms derived from smaller and unrepresentative (i.e., biased) data sets led to wrongful arrests, prompting US vendors to withdraw their facial recognition technologies [1,39]. Separately in 2021, Facebook settled for $650 m in a privacy lawsuit for allegedly using facial recognition without the permission of its users, which is one of the largest privacy-related settlements to date [40].

From a sustainability perspective, the reliance on a phenomenal amount of data for training AI algorithms consumes a substantial amount of computing power, which measurably contributes to CO2 emissions [41]. Reinforcement learning bots on the internet have spread fake news, increased the radicalization of society, and have caused addictive social media behaviors through an intended form of innovative business model [27,42,43].

AI crime is another unintended consequence [44]and makes it more difficult to identify the perpetrators [45].

For the future of our workforce, have we learned from the devastating job losses through business process reengineering in the 1990s [46] to prepare our society better for an ever-increasing degree of automation? AI and robotics are increasingly causing a 'job polarization' or 'dumbbell shape' [47] whereby high-skilled and low-skilled jobs are both in demand, but the former are paid well and the latter are paid poorly. Most jobs are medium-skill jobs in factories and offices, which are most likely to be automated for their predictable tasks [48]. Likewise, at the managerial level, middle management will be most affected by reskilling requirements as the focus here shifts from fewer predictions being made from a manager's experience toward an understanding of how to make decisions from AI predictions [49].

Experts predict with a 75% probability that by the year 2105 AI has learned *how to learn* beyond a point of human assistance [50]. At that point, the concept of moral agency (or 'free will') of machines comes to play [51] and fears are that humans might become an

[1] Refer to Section 5.2 for a more detailed discussion.

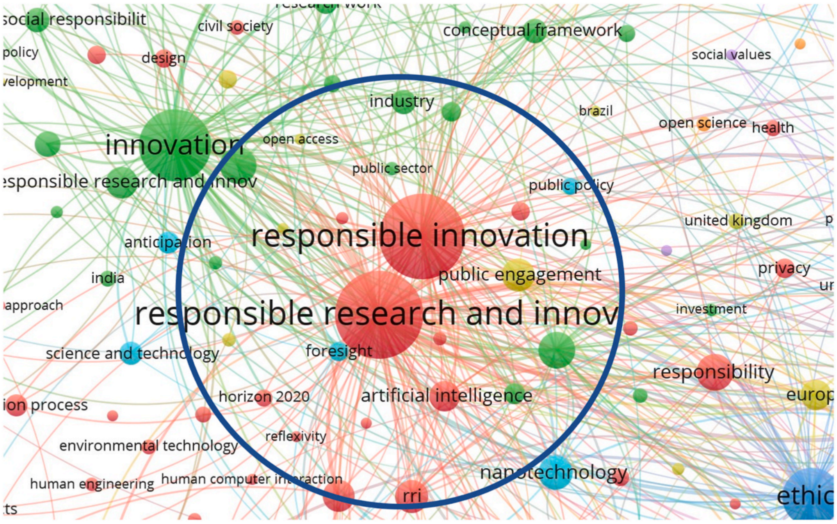

Fig. 1. Bibliometric map of RI concepts – sphere size is proportional to thematic occurrences (source: author, based on VOSviewer-produced visualization).

intelligently inferior species. Think of the dangers of machines enslaving humankind as illustrated in science fiction movies such as 2001: A Space Odyssey or The Terminator. Yampolskiy and Spellchecker [52] argue that this is conceivable if maleficent intent or poor AI design come to play.

It is therefore not surprising that primary studies emphasize the importance of trust-building for the acceptance, adoption, and diffusion of AI in a socially responsible way [53–55]. A report on innovation by the US National Security Commission on AI [56] cautions "if AI systems do not work as designed, or are unpredictable in ways that can have significant negative consequences, then leaders will not adopt them, operators will not use them, Congress will not fund them, and the American people will not support them" (p. 133).

Despite such public declarations and research evidence, a current study predicts that RI will not be widely adopted by RAI until 2030 [57,58]. Opinions differ about the *degree* to which such predictions impact the diffusion of AI, or perhaps could even cause another AI 'autumn' or 'winter' [59–61]. In the meantime, the trust issue in the AI debate has spilled over into the wider information and communication technology (ICT) field [62,63].

1.3. Research objective and questions

This section explains that only a few concepts of RAI are based on RI, which became clear when the earlier Scopus search from Section 1.1 was restricted to journal articles for RI and RAI.[2] Although the centrality of AI in the RI literature is shown inside the concentric circle of Fig. 1, just 147 articles referenced both fields, which equates to 18% of 828 RI articles and yet only 6% of 2489 RAI articles. In other words, the field of RI refers to RAI three times more often. Fig. 2 depicts the publication and referencing proportions between the two fields in a Venn diagram and establishes an arena for the objective/contribution and questions of this research, which will be discussed next.

The *objective and contribution* of this research were to understand how RAI has been developing independently from RI and facilitating a reversal of this trend toward leveraging RI for RAI advancement. This led to the following *research questions:*

- RQ1: How can the corpus of RI be mapped to establish the evolution of its concepts?
- RQ2: How can the corpus of RAI be mapped to establish the evolution of its concepts?
- RQ3: What are the emerging trends in the evolution of RI and RAI?
- RQ4: What is likely is likely to occur in the future for RAI and how can RI be leveraged toward the progression of RAI?

The remainder of this research is structured as follows: First, a literature review in Section 2 discusses the origins of RI and its interdisciplinary nature. A tabulation of extant literature reviews for both RI and RAI is included to underpin the methodological contributions of this research in terms of its comprehensiveness and the need for cross-disciplinary research between the two fields. Boolean search terms are presented for the Scopus database and publication productivity is charted. Next, the design of this research is presented in Section 3 with a novel methodology, systematic science mapping, for conducting a cross-disciplinary review of the evolution of RI and RAI. The science mapping component of this design is discussed in more detail, including its parameterization for

[2] The detailed bibliometric search term for RAI will be discussed in Section 2.5.

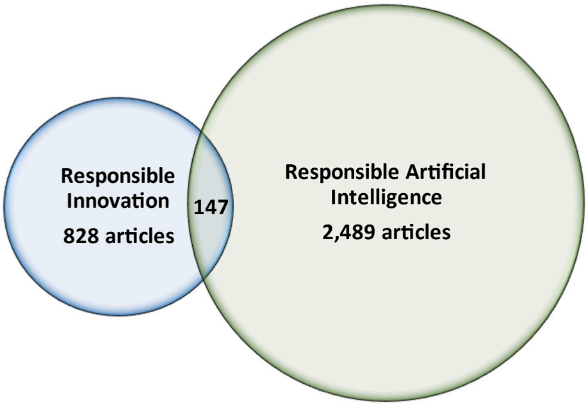

Fig. 2. Venn diagram for the referencing relationship between responsible innovation and responsible artificial intelligence (source: author, based on Scopus data).

replicability by other researchers. Section 4 addresses RQ1 — RQ3 by presenting the science mapping results to establish the evolution of concepts and emerging trends. An emerging 'axis of adoption' of RI by RAI is discussed around the thematic areas of ethics, governance, stakeholder engagement, and sustainability. The discussion in Section 5 is structured around this axis and synthesizes the science mapping results with theoretical insights for identified concepts. The synthesis covers the drivers, catalysts, and inhibitors of RI adoption. From the constructs and their relationships involved, a framework for the adoption of RI by RAI is developed in a systems-theoretic causal loop diagram. Finally, Section 6 summarizes the conclusions and limitations of this research, and makes suggestions for future research.

2. Literature review

This section discusses the origins of RI, and its interdisciplinary nature, and demonstrates a research gap for integrative, cross-disciplinary research between the fields of RI and RAI, based on the particularities of the two fields in theory and practice. It builds a case for RQ1 — RQ3 above, as a prerequisite to addressing RQ4.

2.1. Administrative and Industry Discourses of Responsible Innovation

A widely acknowledged definition of RI from the *policy discourse* is provided by Von Schomberg as "a transparent, interactive process by which societal actors and innovators become mutually responsive to each other with a view to the (ethical) acceptability, sustainability and societal desirability of the innovation process and its marketable products (to allow a proper embedding of scientific and technological advances in our society) [64]." Sustainability here means meeting present needs without compromising the ability of future generations to meet their own needs [65]. It includes 'grand challenges' such as inequality, hunger and access to water, pollution, loss of biodiversity, violent conflicts, deforestation, acidification of the oceans, global warming, infectious diseases, and pandemics [12,66]. Von Schomberg's definition was integral to the European Union's Horizon 2020 program, following on with its new Horizon Europe program until 2027.

[67]. Horizon cites the three pillars of sustainability to benefit from RI: people, planet, and profit [68]. In industry, RI has therefore strong links with corporate social responsibility (CSR) [3], which embeds social responsibility in the day-to-day operations of organizations [69]. It is noted that CSR is broader than RI and sustainability is only one aspect of RI. Nevertheless, the United Nations list RI as one of the implementation means toward their Sustainable Development Goals (SDGs) by 2030 [64].

2.2. The academic discourse of responsible innovation

An alternative definition of RI from the *academic/scholarly domain* is provided by Stilgoe et al. as "taking care of the future through collective stewardship of science and innovation in the present [70]." These authors developed a socially democratic framework of ethical governance attributes – anticipation, reflexivity, inclusion, and responsiveness – which has also been integrated into the EU's Horizon program [11,71] and became a benchmark in the scholarly RI literature [64]. Both the above RI definitions imply a 'human-centric approach', which emphasizes public engagement in research and innovation [29,72]. Science and technology (STS) scholars are also advocating public participation for a 'co-construction' of science and society [73]. Feminist STS denotes the overlap of STS and feminist technoscience studies [74]. And the term 'intersectionality' extends feminist STS beyond a binary gender view, including race, social class, gender, sexuality, and disabilities to understand how the insights from feminist STS can be applied in such a broadened context [39,75]. The term 'data feminism' has been popularized by D'Ignazio and Klein [76].

2.3. The interdisciplinary nature of responsible innovation

As a discipline, RI is related to several other fields, such as social shaping of technology, socio-technical integration research (STIR), science and engineering ethics, applied ethics, human-centered design, participatory design, value-sensitive design, value-conscious design, technology assessment (TA) and technology foresight [6,72,77–79]. Business and engineering schools have been the most prolific publishers in the management of *technological innovation* [80]. But in RI, the social sciences and humanities have an equally strong publication presence. Fig. 3 depicts a breakdown of the RI literature by subject area in the Scopus database.

A noteworthy point here is that Scopus does not assign an article's subject area from its keywords. Instead, the article inherits its subject area from the classification of its journal, book, or conference proceedings [81]. For example, the *Heliyon* journal is classified in Scopus as multidisciplinary, which means that it publishes articles from multiple disciplines, which are not necessarily multidisciplinary articles themselves. Nevertheless, the interdisciplinary nature of RI is illustrated through the diversity of its major subject areas: the social sciences; business management and accounting; engineering; and arts and humanities.

2.4. A tabulated review of previous literature reviews of RI and RAI

This section focuses on the methodological contribution of this research by tabulating extant literature reviews for both fields, RI and RAI. A need for cross-disciplinary research between the two fields is established.

Fourteen types of literature reviews have been identified by Grant & Booth [82]. Four types of reviews are particularly relevant to this research: bibliometrics, science mapping, systematic literature reviews, and thematic analysis. Bibliometrics have increasingly been used for reviews in the AI field since the beginning of this century to analyze the publication *performance* of authors, institutions, journals, or countries [83,84]. Science mapping is a subfield of its parent discipline, scientometrics [85], which analyses the concepts of scientific fields and/or uncovers their *evolutionary nature* [86,87]. *Systematic literature reviews (SLRs)* are widely used in health-related research and are considered more rigorous than literature reviews in business because they facilitate replicability by researchers and minimize bias in the identification, selection, synthesis, and summary of sources [88,89]. Table 1 compares the literature reviews found in the English language for RI and RAI. It is shown which studies include systematic reviews, publication performance analysis, the evolution of themes, and/or a thematic analysis, i.e., a qualitative analysis that focuses on themes within the body of literature [90].

Lubberink et al. [109] conducted the first SLR of RI covering three bibliometric databases with a focus on empirical research. Several other literature reviews have been published for RI as a whole [96,101,108] or specific RI subfields [64,71,91,92,94,95,107,111]. Heersmink et al. [110] provided the first bibliometric mapping of RAI-related concepts in AI's parent field of information and communication technology (ICT). Since then, RAI concepts have been mapped for various AI technologies and specific subfields of interest [83,93,97–100,102,105,106].

No cross-disciplinary literature review across RI and RAI could be found to date, which is one of the methodological contributions of this research (refer to Sections 4 and 5). Table 1 also demonstrates a second methodological contribution as this research is the most comprehensive and up-to-date literature review of RI and RAI by any measure (i.e., scale in terms of the number of publications reviewed as well as the inclusion of a systematic review, and analysis of performance, themes, and evolution). The next section provides a quantitative analysis of publication productivity for both fields.

2.5. A quantitative review of publication productivity

Bibliometric research often uses Google Scholar, Clarivate's Web of Science (WoS), or Elsevier's Scopus databases [112–115]. All are suitable due to their multidisciplinary coverage [113,116], which aligns with the interdisciplinary nature of RI as discussed in Section 2.3. However, searches in these databases produce different results as several studies demonstrate [112,113,115–118]. Google Scholar is the largest database, followed by Scopus and then WoS [118]. What makes Google Scholar less suitable for bibliometric research is that it also captures nonacademic publications and it does not provide a bulk export facility for further analysis with bibliometric tools [119,120]. Scopus was chosen for this research over WoS because it covers a wider range of journals [116,121]. Indeed, other recent research on AI found that the majority of articles outside the WoS database could be found in Scopus [114].

The search process in Scopus started with Boolean terms to find publications relating to *RI*. The earlier discussed RI synonyms in Section 1.1 were included to find all relevant documents (i.e., 'responsible innovation', 'responsible research and innovation', and 'responsible development'). A search for the *'wider' RI field* was also conducted by including RI-related areas (i.e., technology assessment, technology foresight, value-sensitive design, value-conscious design, social shaping of technology, and science and engineering ethics). The search for *RAI publications* required a more intricate Boolean search because the term AI is widely used and loosely defined [1,93,122,123]. Over time, AI developed into various paradigms: algorithmic AI (such as machine/deep learning and big data), symbolic AI (such as expert systems), and metaheuristic AI such as nature-inspired and quantum computing [14,15,91]. Across these paradigms are disciplines and technologies such as data science, business intelligence, robotics, big data, robotic process automation, and autonomous systems [124–127]. Such AI-related terms had to be included in the search for RAI publications because publications sometimes do not refer directly to AI [14]. Various ethical terms also had to be included for the same reason [85]. The searches were restricted to journal articles. The following Boolean search term for RAI was used (in Scopus syntax for replicability by other researchers):

(TITLE-ABS-KEY ("ethic*") OR TITLE-ABS-KEY ("unethic*") OR TITLE-ABS-KEY ({privacy}) OR TITLE-ABS-KEY ({XAI}) OR TITLE-ABS-KEY ("explainab*") OR TITLE-ABS-KEY ({moral})) AND (TITLE-ABS-KEY ("data science") OR TITLE-ABS-KEY ("big

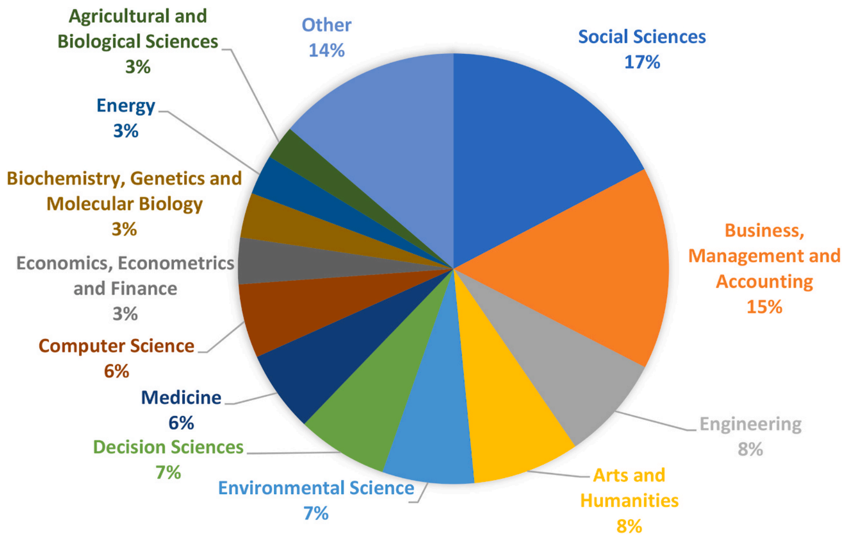

Fig. 3. RI publications by Scopus subject area (source: author, based on Scopus data).

data") OR TITLE-ABS-KEY ({AI}) OR TITLE-ABS-KEY ("artificial intelligence") OR TITLE-ABS-KEY ("machine learning") OR ("deep learning") OR TITLE-ABS-KEY ("expert system*") OR TITLE-ABS-KEY ("neural net*")) AND (LIMIT-TO (SRCTYPE,"j")) AND (LIMIT-TO (DOCTYPE,"ar")) AND (LIMIT-TO (LANGUAGE,"English"))

Fig. 4 depicts the number of Scopus documents by year for RAI, RI, and RI-related fields.

In total, 23593 documents were found for RAI in Scopus between the years 1962 and 2020, which is a similar order of magnitude to the 27333 documents for the RI-related fields in the same period. However, RAI has a higher growth rate and exceeds the number of annual RI-related publications since 2016. With just 1429 Scopus publications by 2020, RI is still an embryonic field. Interestingly, when RI's related fields are included the number of publications increased almost twenty-fold with an upward shift in publications since the turn of this century. Due to the small order of magnitude of RI publications compared to RAI, a logarithmic scale was used in Fig. 5 to juxtapose the academic publication productivity of RI, RI-related fields, and RAI.

It can be seen in Fig. 5 that the literature productivity on RI is lagging substantially behind RAI. When the functional forms are compared, it appears that RI publication volumes are time-shifted by about 6 years behind RAI's.

3. Methodology – systematic science mapping

This section discusses the research design and the science mapping method, including its parameterization.

SLRs are often conflated with metanalysis to provide a synthesis of previous quantitative studies toward estimating trends and assessing variations [128]. In this research, the application of metanalytic procedures was not feasible for two reasons: RAI concepts in the literature are substantially inconsistent [27,85], and more than 3317 (828 RI plus 2489 RAI) articles needed to be analyzed [129]. Science mapping was more suitable for addressing the holistic nature of the research questions in this study [130] and has previously been used in combination with SLRs for AI [131] or to add a quantitative perspective to STS in the context of technology and society interconnectedness [132]. The combination of SLRs with science mapping is sometimes referred to as a 'systematic literature network analysis' [22,133].

3.1. Research design

The research design is depicted in Fig. 6, based on a PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flowchart [134]. The replicability of this research by other researchers was an important consideration, which is why the parameterization of science mapping is also elaborated on.

The following steps were followed at the science mapping stage of Fig. 6:

(1) Map the RI corpus from 828 articles in the Scopus database.
(2) Map the RAI corpus from 2489 Scopus articles.
(3) Identify evolutionary differences and commonalities between RI and RAI.

A synthesis of the science mapping results was then used to develop a systems-theory-based causal loop diagram to make recommendations for the adoption of RI by RAI.

Table 1
Comparison of extant literature reviews for responsible innovation and responsible artificial intelligence[31] (source: author).

Authors	Systematic Review	Performance Analysis	Thematic Analysis	Evolution of Themes	Sample	Field and Bibliometric Database
Fosso Wamba et al. [91]		✓	✓	✓	1048 papers, 1991–2019	AI, social innovation, Web of Science (WoS)
Obradović et al. [92]	✓	✓	✓		239 articles, 2003–2019	Open innovation in manufacturing, Scopus and WoS
Stahl et al. [93]			✓		Mixed methods research	Algorithmic AI
Granstrand and Holgersson [94]	✓		✓		22 articles, No period specified	Innovation ecosystems, WoS
Gonzales-Gemio et al. [64]	✓	✓	✓		102 articles, 2000–2020 (April cutoff)	RI in SMEs, WoS
Harsanto et al. [95]	✓	✓	✓		17 articles, 2013–2020	RI in emerging economies
Nazarko [96]		✓	✓		841 papers, 2009–2019	RI in Scopus
Kuc-Czarnecka and Olczyk [97]		✓	✓		892 WoS papers to 2020	Big Data
Di Vaio et al. [98]	✓	✓	✓		73 WoS papers 1990–2019	Sustainability
Hernández-Orallo and Vold [99]	✓		✓		1500 research papers 1970–2017	Safety
Loi et al. [100]			✓		20 declarations from industry, government & NGOs	All AI technologies
Nazarko [101]		✓	✓		360 papers, 2009–2018	RI in Scopus
Lehoux et al. [71]	✓		✓		254 articles, 2000–2016	RI in health, PubMed, EMBASE, PsycINFO, IBSS, ProQuest, PAIS, WoS
Vakkuri and Abrahamsson [102]	✓		✓		83 articles 2012–2020	All AI technologies
Jobin et al. [103]	✓	✓	✓		84 declarations from industry, government & NGOs	Governance, regulation & policy
Tran et al. [104]	✓	✓	✓		204 WoS articles, 1977–2018	AI in Health
Ronzhyn and Wimmer [105]	✓		✓		74 papers	eGovernment
Zawacki-Richter et al. [106]	✓	✓	✓		146 articles 2007–2018	Higher education
Alonso et al. [83]		✓	✓		3737 Scopus articles 1961–2017	Explainable AI (XAI)
Reijers et al. [107]	✓		✓		136 papers, 1990–2015	Ethics in RI, Scopus, WoS and Springerlink
Burget et al. [108]			✓		235 articles, no period specified	RI in EBSCO and Google Scholar
Lubberink et al. [109]	✓				72 empirical articles, unrestricted period	RI in Scopus, WoS and Abi Inform
Heersmink et al. [110]			✓		1027 papers, 2003–2009	ICT
Di Vaio et al. [111]	✓	✓	✓	✓	114 articles 1990–2021	RI and ethical corporate behavior in Scopus and Google Scholar
This research	✓	✓	✓	✓	828 RI and 2489 RAI articles, 1962–2020	Cross-disciplinary study between RI and RAI in Scopus

3.2. *Science mapping method*

The articles were distributed across four periods in a way that minimized the suppression of emerging themes and domination of established themes. The distribution of articles across periods is shown in Table 2.

Science mapping often relies on co-occurrences of articles' keywords, or 'co-word analysis', as a common technique for mapping the evolution of a field [135]. Co-word analysis dates back to Callon & Turner [136] and employs statistical clustering techniques to group publications into themes based on similarity measures for their keywords. Co-word analyses have been deployed by previous combinations of systematic reviews with bibliometric methods [22,137–139]. As the first indicator of an article's focus, the *co-occurrence* parameters in Table 3 were used as a minimum threshold for words appearing together in an article's title, abstract, or keywords.

A threshold level of 2 was used for the RI articles and a level of 3 was applied to the RAI articles, due to the difference in their overall number of articles. Subsequently, articles were clustered into themes for each period according to the inclusion metric to emphasize dominant themes [135]. Inclusion is less sensitive to the volume of publications than other metrics [140], which was the key issue by an order of magnitude between corpora of RI and RAI. Inclusion has also been proven useful with overlapping themes [141], which is a

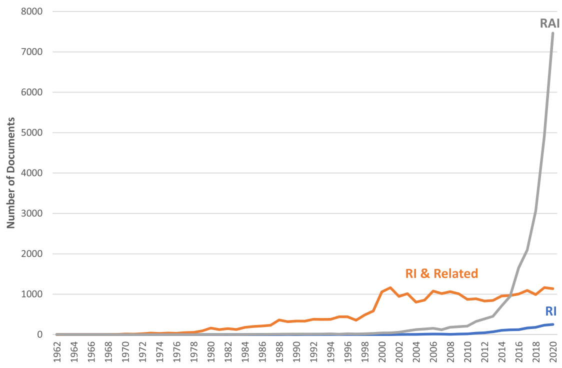

Fig. 4. Number of Scopus documents by year for RI, related fields, and RAI (source: author, based on Scopus data).

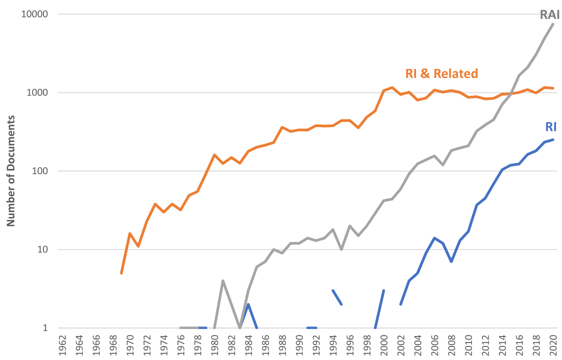

Fig. 5. Logarithmic scale of Scopus documents by year for RI, related fields, and RAI (source: author, based on Scopus data).

problem, particularly with RAI [27,85].

4. Science mapping results

This section discusses the science mapping results for mapping the corpora of RI and RAI to establish the evolution of their concepts (i.e., RQ1 and RQ2). Steps 1)—3) of section 3.1 (Research Design) were followed. Emerging trends in the evolution of RI and RAI are presented (i.e., RQ3).

4.1. Evolutionary visualizations

The evolutionary maps in Figs. 7 and 9 depict the thematic evolution of RI and RAI, respectively.

Solid lines across periods show strong connections among themes that share at least the number of keywords as per the *Network (NW) Edge Reduction* parameters of Table 3. In some cases, a theme may even become absorbed by another one, such as Governance, Regulation & Policy being absorbed by Ethics in the 2020 period of Fig. 7. Dashed lines denote themes sharing fewer keywords across periods than solid lines, which denotes a weaker connection. The width of solid or dashed lines is proportional to the inclusion index, indicating the strength of a relationship. Tracing solid and dotted lines defines a thematic area, which depicts how themes have developed into others and across sub-themes. These thematic areas are shaded in blue for Governance, Regulation & Policy and in amber for Ethics in Figs. 7 and 9.

The size of the spheres in Figs. 7 and 9 is proportional to the *h-index* of their associated themes. The h-index measures the impact of themes by combining quantitative factors (i.e., publication counts) and qualitative factors, i.e., citations [47,142]. The average h-indexes across all periods of Figs. 7 and 9 were 15 and 14, respectively. Such high average h-indexes suggest that the themes identified had a high impact on the scholarly literature of RI and RAI.

In the RI literature, the theme Governance, Regulation & Policy maintained its connection with Stakeholder Engagement throughout all periods to form the blue thematic area in Fig. 7. Sustainability joined that area in the period 2018–2019.

[3] Sorted by date.

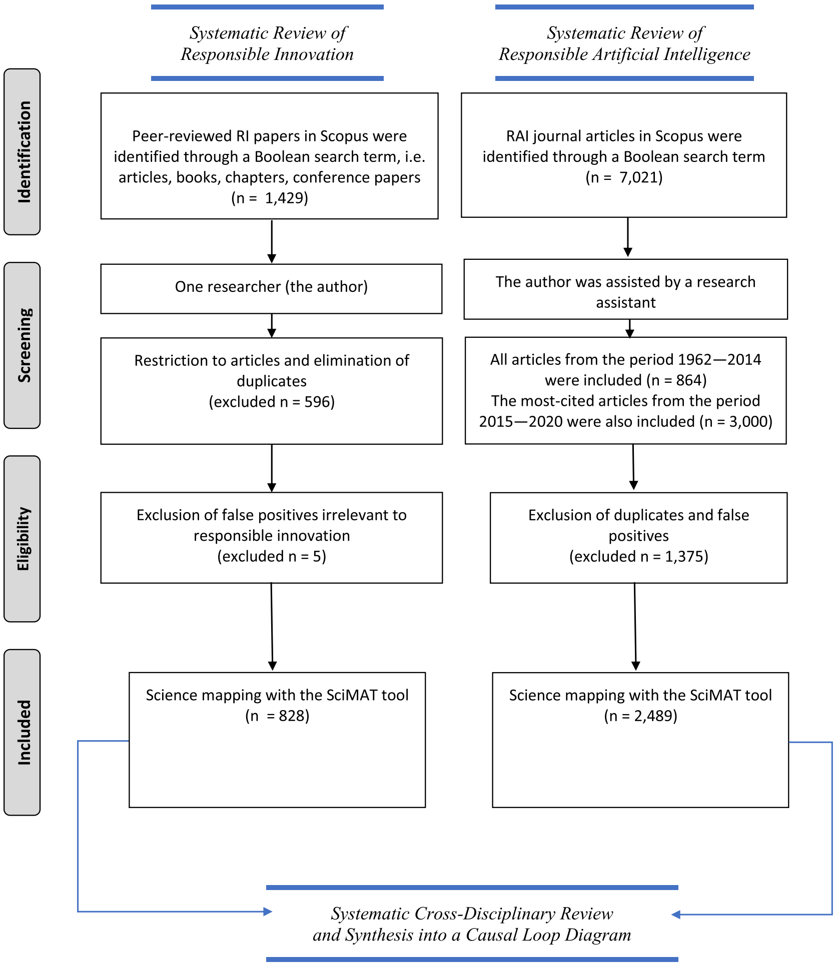

Fig. 6. Systematic review flow chart, based on PRISMA (source: author).

Table 2
Number of Scopus articles by period.

Period	RI Corpus	RAI Corpus
1962–2013	122	325
2014–2017	296	593
2018–2019	228	680
2020	182	891

Table 3
Science mapping parameters.

Parameter	RI	RAI
Co-Occurrence	2	3
Edge Reduction	2	3
Min Network	3	4
Max Network	6	11

Technology assessment (TA) and technology foresight (TF) have both been foundational since the earliest period 1978–2013 [143] in Fig. 7. TF relies less on expert advice than TA and typically involves a wider group of stakeholders such as local citizens or laypersons [144]. TF is often conflated with 'future(s) thinking' or 'horizon scanning', but they are distinct concepts [145,146]. The former is more of a mindset whereas the latter is often used as a method within the more process-oriented TF [147]. TA and TF are together referred to as TAF for the remainder of this text. As a thematic area, TAF is shaded in amber and has strong overlaps with the

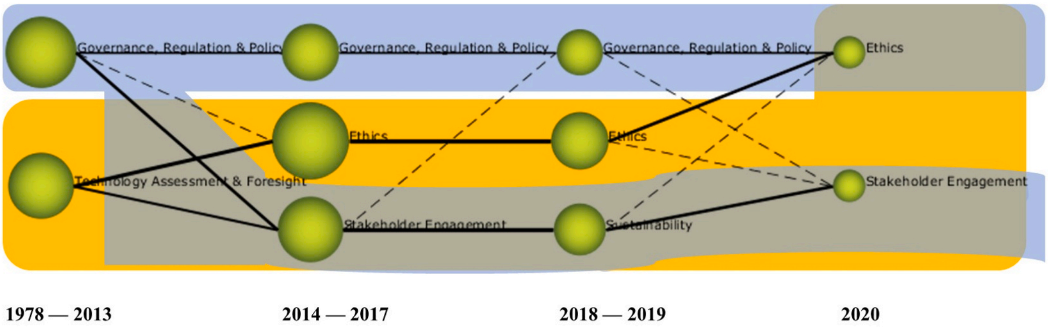

Fig. 7. Evolutionary map for RI with thematic areas – sphere size denotes the h-index of articles (source: author, based on SciMAT-produced visualization).

Governance, Regulation & Policy area through the Stakeholder Engagement theme. TAF became absorbed by Ethics and Stakeholder Management in the 2014–2017 period.

The longitudinal stability of Fig. 7 is assessed next with the help of Fig. 8.

The total number of keywords in each period is encircled in Fig. 8. The horizontal arrows between consecutive periods show their number of shared keywords and their proportion in brackets relative to the previous period (inclusion index). The angled connectors show how many keywords were added or dropped from one period to the next. Fig. 8 shows that the number of new, transient, and overall keywords is small to the extent that the last period contains just 38% more keywords (51) than the first period (37). In addition, the inclusion index decreases over time (0.62, 0.53, and 0.49). These observations suggest that RI is still an embryonic field and in a state of flux, which is corroborated through separate research by Alcaide–Muñoz et al. [130].

Next, the evolutionary map of RAI is presented in Fig. 9 and its stability over time is discussed, based on Fig. 10.

As is the case for RI, Governance, Regulation & Policy features in Fig. 9 as a thematic area for RAI shaded in blue color. Likewise, Ethics is also a dominant thematic area right from the first period 1962–2013 and shaded in amber. Robotics is part of that thematic area and emerged in the period 2018–2019. Different from RI and its reliance on TAF, however, no *methods* for implementing RAI were found to be statistically significant for the parameters of Table 3. This suggests an implementation gap in RAI, which will be discussed further in Sections 5.2 and 5.4.

The stability of Fig. 9 over time is explored next in Fig. 10.

The 2020 period contained almost four times the number of RAI keywords as compared to the first period 1962–2013. In addition, the inclusion index increases by 5% points period on period (0.48, 0.53, and 0.58), which is encouraging for robust conclusions.

4.2. Conceptualizations of emerging trends

This section addresses RQ3: *What are the emerging trends in the evolution of RI and RAI?* To answer this question, a deeper look at the endpoints of the thematic areas in the evolutionary maps from Figs. 7 and 9 needs to be taken. That is, a look to understand the internal structure of the theme clusters for the year 2020. This might give further insights into evolutionary commonalities and differences between RI and RAI. The internal cluster structure is represented by 'cluster network graphs' with themes as nodes. The central theme of a cluster gives the cluster its name [86]. The thickness of their connecting lines is proportional to the inclusion metric [148]. The size of the spheres is proportional to the number of articles in the cluster. The cluster networks for RI and RAI are juxtaposed in Figs. 11 and 12, respectively.

Fig. 11a) shows three dominating applications of RI in AI, Nano- and Biotechnology, and Geoengineering. TAF is the major method for ethical assessments. Governance, Regulation & Policy have almost the same weight in this cluster as its central theme, Ethics, with strong links to all other cluster themes. Sustainability in Fig. 11b) has an even stronger weight than the central theme, Stakeholder Engagement. The latter has more interactions with the other themes in the cluster, which is why it became the central theme [47]. The EU and Universities are strong stakeholders in the pursuit of Social Responsibility. Science Shops were pioneered in the Netherlands in the 1970s [149] and are explored nowadays as part of the EU's Horizon programs as a vehicle for the engagement of the public with other stakeholders [150]. It is, therefore, no surprise that Science Shops have the strongest link with Stakeholder Engagement in Fig. 11b) despite their embryonic documents count in RI for 2020.

Governance, Regulation & Policy in Fig. 12a) is fragmented into ten isolated subthemes that do not share internal links in the RAI cluster for 2020. On inspecting the articles of that cluster, however, the highest cited documents and more than half of all cluster documents relate to Privacy as a common tenet. Ethics is the largest cluster in 2020 for RAI with many interconnected themes in Fig. 12b). Several RI-related themes feature strongly in the cluster such as Innovation, Responsibility & Accountability, RI, Fairness, Stakeholder Engagement, and the EU's Horizon programs. Sustainability is the smallest RAI cluster. But it includes interconnected RI themes such as TAF and Social Responsibility. By way of clarification, Long-Short-Term Neural Nets in Fig. 12c) are useful for time-series-based predictions and have been applied in environmental and energy sciences [151].

When Figs. 11 and 12 are compared holistically, a set of common themes emerges between RI and RAI for the 2020 period: Ethics, Governance/Regulation/Policy, Stakeholder Engagement, and Sustainability. These themes form an axis in both figures, which is

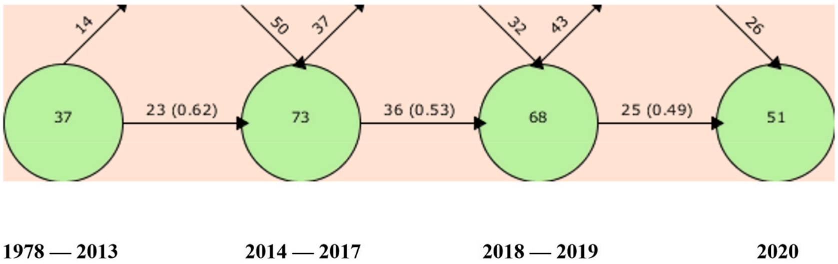

Fig. 8. Stability of the RI evolutionary map (source: author, based on SciMAT-produced visualization).

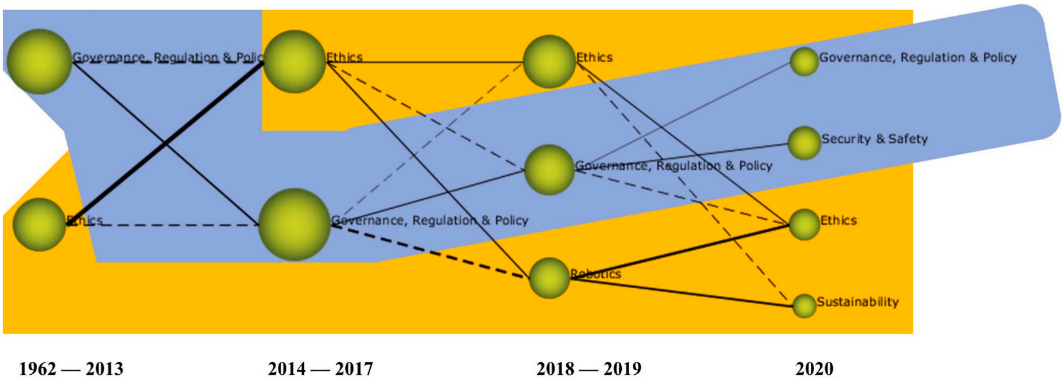

Fig. 9. Evolutionary map for RAI with thematic areas – sphere size denotes the h-index of articles (source: author, based on SciMAT-produced visualization).

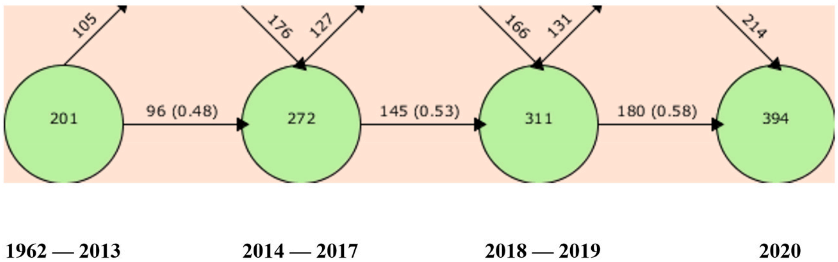

Fig. 10. Stability of the RAI evolutionary map (source: author, based on SciMAT-produced visualization).

encircled by dashed lines in green color. Space restrictions do not allow for the listing of cluster networks for the previous periods. But when they were inspected, this axis can be traced back in RAI to the 2014–2017 period. The axis could therefore be interpreted as RAI's recent 'axis of adoption' of RI themes, which started somewhere in the 2014–2017 period.

5. Discussion and Synthesis of Results

RQ4 asks: *What is likely is likely to occur in the future for RAI and how can RI be leveraged toward the progression of RAI*? To address it, this section is structured around the 'axis themes' of Figs. 11 and 12 that drive RAI's adoption of RI: ethics; governance, regulation and policy; stakeholder engagement; and sustainability. Theoretical insights for each axis theme are discussed under a separate heading and synthesized with the science mapping results from Section 4. The synthesis covers the drivers, catalysts, and inhibitors of RI adoption.

5.1. Ethics

RAI has been inspired by Wiener's [152] seminal work on the "automatic age" and its ethical and societal implications from ICT. Wiener laid the foundation for the RAI principles of freedom, justice, and benevolence [153]. Since then, the ICT field has focused on the ethical use of machines by humans, whereas the RAI discourse relates more to the behavior of machines toward humans, society as

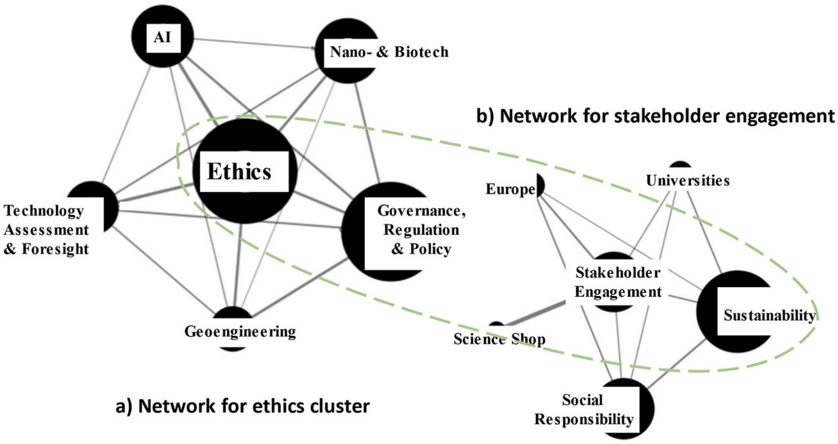

Fig. 11. Cluster networks for responsible innovation – sphere size denotes publications count (source: author, based on modified SciMAT outputs for readability).

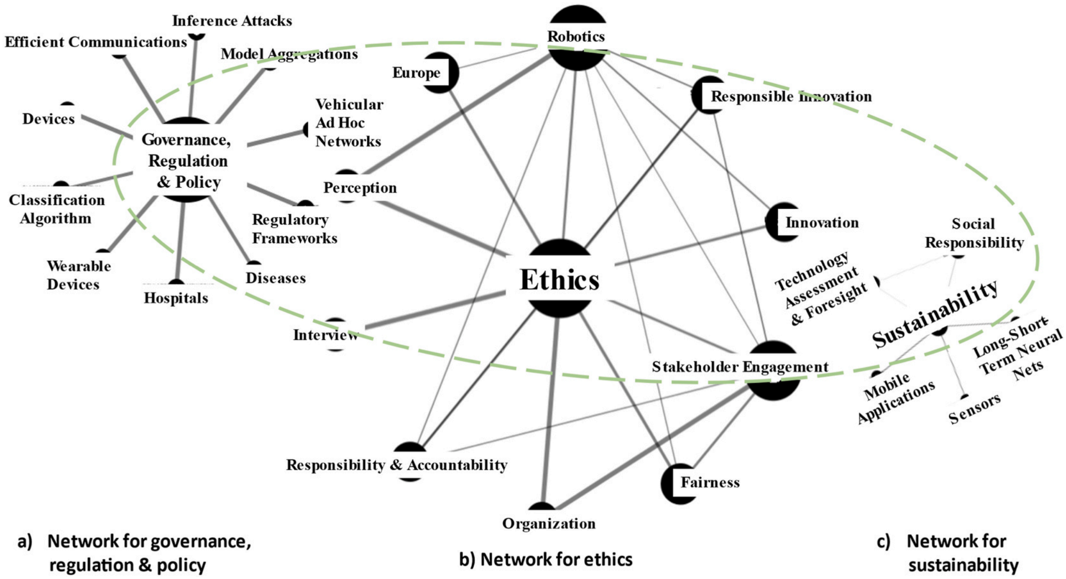

Fig. 12. Cluster networks for responsible artificial intelligence – sphere size denotes publications count (source: author, based on modified SciMAT outputs for readability).

a whole, as well as other machines [154–156].

Stahl et al. [93], found that philosophical ethical theory and moral debates were not significant themes in scholarly RAI research. Indeed, the literature sidesteps ethical theory debates by focusing on the definition of ethical principles. This focus on principles without a debate of ethical theory is referred to as principlism [157–159]. The neglect of normative ethical theory in the EAI debate is a gap in the literature, including deontology when principles become operationalized and governed [158,159]. Such a gap is significant because RAI is a value-laden area and the personal values of AI designers influence the way machines either augment decisions (with humans in the decision loop) or fully automate decisions [79,160,161].

5.1.1. Inconsistent conceptualizations of ethical principles

Significant overlaps and differences exist *between* RI and RAI fields on the principles of responsibility, beneficence, non-maleficence, and fairness [8,66]. They are compounded by overlaps and variances across ethical concepts *within the RAI corpus* [23,27]. For example, *responsibility* needs to be taken for the ethical principles of beneficence, non-maleficence, fairness, and governance [162]. Thus, responsibility takes the social embeddedness of technology and ethical aspects explicitly into account [163]. Social embeddedness also makes it obvious that responsibility is overlapping with the *fairness* principle [103]. Much of the fairness debate overlaps with the issue of bias in RAI [164]. Beneficence and non-maleficence are more complicated, due to their interdependent relationship. For example, social and companion robotics are active RAI research fields on *beneficence*, but intimate robotics is still considered taboo and rarely broached in the scholarly literature or conferences [165]. On the issue of whether the development of intimate robotics is ethically appropriate, there are feminist perspectives [166], queer studies [167], and other perspectives. Regardless of the perspective taken, an ethical obligation emerges for the technology to prevent harm under the principle of *non--maleficence* [168].

5.1.2. Eurocentric ethical norms

A notable 74% of RI publications In Scopus received research funding with 26% of all publications being funded by the European Commission. Just on the Horizon 2020 program alone, more than €100 m was spent between 2014 and 2020 on RI and RAI projects [101]. This demonstrates the importance of Europe's agenda for both fields. By the same token, such *Eurocentrism* [refer to Fig. 11b) and 12b)] is a barrier to global RI/RAI acceptance, due to cultural and regulatory differences with the rest of the world and indeed, even within the EU [96,169].

More specifically, public RAI declarations by governments, industry, and NGOs are dominated by wealthy Western countries from the Global North and underrepresented by developing countries in the Global South [170]. Ethical norms are not universal and the selection of RAI codes from the Global North over others presents a problem for the global society as the 'moral machine experiment' for self-driving cars has shown [171]. Awad et al. [169] conducted this experiment for a safety-engineering project to solve ethical dilemmas in unavoidable accidents. More than 2 million people from all over the world were presented with hypothetical crash situations and had to decide on whether to stay on course or swerve, i.e., who is spared and who is sacrificed. The experiment demonstrated that RAI is a value-laden area, and the personal values of AI designers influence the morality of machines.

Spiritual perspectives are also biased by heavy attention to US and European views, such as the principles of the ten commandments in Abrahamic religions [172]. Where do Hinduism, Buddhism, Confucianism, Taoism, Shintoism, or various aboriginal beliefs come in Refs. [173,174]?

5.2. Governance, regulation, and policy

The term 'governance' is a broader term capturing interrelationships among research, innovation, and politics [149]. Governance in RI is strongly intertwined with ethics to ensure stakeholder engagement throughout the entire research and innovation life cycle [8, 71]. This can be seen in Fig. 11a) where governance and ethics are part of the same cluster network. Both themes share the same weight (sphere size) and are connected with every other theme in the cluster. Therefore, the two themes are sometimes combined into a single term 'ethical governance' [175]. Fig. 7 demonstrates the link of governance, regulation, and policy with stakeholder engagement through a dashed line. In RAI, on the other hand, Fig. 12a/b) shows governance and ethics in separate cluster networks with governance being weighted heavier. It is therefore not surprising that 35% of all RAI articles in Scopus relate to governance, regulation, or policy [19].

5.2.1. Government regulation

Governments have been most prolific in releasing public RAI declarations with a little over half of them, followed by industry and non-government organizations (NGOs) with about a quarter's share each [176]. *Government* activity relates mainly to policy statements, including the High-Level Expert Group on AI appointed by the European Commission, the expert group on AI in Society of the Organization for Economic Co-operation and Development (OECD), Fairness, Accountability, and Transparency in ML (FATML) in the US, the Advisory Council on the Ethical Use of AI and Data in Singapore, and the committee on AI of the UK House of Lords [177].

In April 2021, the EU released its proposal for AI regulation, which can be expected to become EU law in this decade and industry will need to prepare for its compliance. The regulation defines three categories of AI-related risk [178]: *Unacceptable*-risk applications will be banned, such as social scoring or manipulative techniques. *High*-risk applications will be heavily regulated, such as recruiting consumer creditworthiness or administration of justice. *Limited- or minimal*-risk applications will have light regulations such as chatbots and spam filters. This regulation will affect organizations trading with the EU and is likely to cause a global ripple effect, based on precedence from the EU's General Data Protection Regulation (GDPR) in the privacy area [122,179]. Particularly, with privacy being the dominating RAI tenet in the articles contained in Fig. 12a), as well as being a core element of RI [180].

5.2.2. A principles-to-practice gap

Separate from regulation, both fields RI and RAI still show a gap when ethical principles become operationalized and governed in organizations [181,182]. This gap is known as the principles-to-practices gap [28] and is an emerging theme in both fields [3,79,183]. To address this gap, thirty-five RI-inspired tools have been found in a literature review by Reijers et al. [107]. 106 tools were found by Morley et al. [184] just two years later with most of them originating *independently* from the RI field. VSD is one of the most widely used RI methods that sometimes also finds its application in RAI [185]. However, organizational governance is an *ongoing process* and is inadequately addressed by methods or software tools [157].

5.2.3. Organizational governance processes and structures

More recent integrations of RI governance into RAI *combine* processes, tools, and technical specifications that are more meaningful in RAI practice. For example:

- The Institute of Electrical and Electronic Engineers (IEEE) launched the P7000 standards projects in 2019 to address ethical issues in AI (Peters et al., 2020). Schiff et al. [28] propose a TAF variant, based on the IEEE 7010 standard, which has twelve domains for assessing the impact on well-being.
- The EU's Human Brain Project combines empirical neuroscience with AI and was launched in 2013 as a ten-year initiative involving around one hundred research institutions [186]. Ethical governance was implemented through an independent ethics advisory board and by developing standard operating procedures, including record-keeping for audits and ethical approvals before research projects commenced [187].
- The UK Engineering and Physical Science Research Council (EPSRC) framework for AREA has been particularly influential [11]. It is based on anticipating consequences, reflecting on motivations, processes, and products, stakeholder engagement, and acting on problems uncovered [70].
- Combining reflection and social embeddedness, Martin [160] developed a threshold model to determine how the responsibility for AI-based decisions should shift between users and AI designers. Such a delegation of roles determines ultimate accountability for decision outcomes and needs to be considered at the AI design stage [188]. This is congruent with general recommendations toward a design-led approach at the front-end of RI [189].
- Tools have been developed for translating abstract RAI principles into technical specifications and establishing a procedural regularity at repeated intervals, covering the 'validation, verification and evaluation' of AI design [190,191].
- Gartner proposes to integrate humans, processes, and tools as follows [192]:
  1) Organization-wide AI governance committees should promote RAI by providing standards, guidelines, and interventions; and
  2) Members of the data scientist team should be appointed to use tools for ethical validation of AI models they did not develop.
- For the governance of RI in the scientific domain, the EU has devised the 'Ethics Governance System for RRI in Higher Education, Funding and Research Centers', referred to as ETHNA [193]. It is funded by Horizon 2020 and seeks to promote the EU's RI governance attributes as discussed in Section 2.2 (anticipation, inclusion, reflexivity, and responsiveness) and applies to research integrity, governance, gender perspective, public engagement, and open access [194]. González-Esteban and Calvo [195] propose the adoption of ETHNA for RAI in scientific research. Herrmann and Cameron [196] provide a less European-centric RAI governance framework specifically for mixed-methods researchers as users of AI.

5.3. *Stakeholder engagement*

The significance of stakeholder engagement in RI is illustrated in Blok and Lemmens' [4] definition of RI = "innovation + stakeholder engagement". As an RI concept, stakeholder engagement goes back to the EU's earliest advocacies in the 1990s and in the US in the early 2000s [197]. In the RI field, early interdisciplinary engagement of researchers from the social sciences and humanities has often involved so-called 'laboratory studies' [198]. Industry engagement is dominated by multinational technology corporations that focus on RAI principles for designers and governance [122]. Smaller organizations and consumers are underrepresented. It is therefore no surprise that stakeholder engagement is conspicuously absent as a theme on the evolutionary map for RAI in Fig. 8 and is 'tucked away' inside the ethics cluster network in Fig. 12b).

Vincent [197], Paskaleva and Cooper [199], and Di Vaio et al. [111] are reinforcing the need for governance to ensure stakeholder engagement amounts to more than just 'political correctness' especially because different stakeholders often have divergent motivations in co-producing and co-evaluating innovations. Although not part of the research questions, the application of AI to the innovation process itself is theoretically intriguing [80]. But it could not be found as a theme in the evolutionary maps and cluster networks of Fig. 7–12. Haefner et al. [200] note there is only sparse evidence of such AI applications to date. A conceivable example might be the use of AI to determine the most relevant stakeholders for their engagement in RI [8].

5.3.1. *Citizen engagement*

The EU implementation of RI has a specific slant toward five thematic elements: gender equality, science education, open innovation and science, research ethics, and *public engagement* [101,201]. However, engagement with the public on AI's societal impact has only been recent with 80% of RAI declarations by government, industry, and NGOs being less than five years old [103]. The recent growth of such declarations to more than 400 is an encouraging trend [176]. This trend and the relatively heavy weight of the stakeholder engagement theme in Fig. 12 b) suggest that it is an emerging theme in RAI research and practice. A literature review of RI in emerging economies by Harsanto et al. [95] established an emphasis on ex-post public engagement over ex-ante foresight.

5.3.2. *University and NGO engagement*

The *NGO sector* is highly diversified and includes professional organizations (such as the IEEE), think tanks, advocacy groups (such as the Toronto Declaration), and collaborative work led by academia, such as the Montreal Declaration [202]. The influence of NGOs over the public and private sectors remains to be seen although the public sector does refer to NGOs for input into national policy [203].

A*cademia* plays an important role to advise on policy, sustainability, and social responsibility issues as shown in Fig. 11b). Indeed, most RI research is done by universities [4]. However, research in 12 countries found that implementation resistance toward RI 'on its own turf' exists in the academia, due to "increasingly managerialist and regulatory practices of governance and oversight, and that may be in tension with underlying assumptions of norms and values of academic life cultivated over centuries" [201]. Research by Owen et al. [204] in the UK confirmed a limited RI uptake in university research for similar reasons.

Explainable AI (XAI) has recently emerged in academic research as an evolving RAI branch to address the ethical principles of transparency, interpretability, and explicability as enablers for responsibility and accountability [83,205]. Although there is no agreement today on what XAI exactly means [206], various approaches have been developed, such as tests for representative data, models that can be simulated, decomposable models, and algorithmically transparent models [207]. XAI is an obvious prerequisite for stakeholder engagement [162].

5.3.3. *Open science*

The EU's thematic elements of open science and open innovation were originally seeded by stipulating open access to publications and have been expanded since 2016 [208]. Open science now requires universities to share research data, publish as open access, use of open-source software, and replicability of the research by third parties [209,210]. In the RI context, this also requires sharing the assessments of the research in terms of its purposes, risks, uncertainties, implications, and potential uses of the research [70].

5.3.4. *Open innovation*

The term open innovation (OI) relates more to *industry* [211] with a recent definition being "a distributed innovation process based on purposively managed knowledge flows across organizational boundaries …" [212]. In addition to product innovation, OI has also been identified as a promising approach to service innovation in the heavily AI-reliant service economy 3.0 [199,213]. OI may therefore be considered one of the most innovative approaches in the last decade [80]. EU policy seems to increasingly relate RI to the '3Os': OI, open science, and openness to the world [96]. However, a lack of unified RI approaches, professional standards for implementation, and concern over intellectual property have been hindering the adoption in the industry [109,183]. The time and resource intensity of stakeholder engagement has been another deterrent for the RI adoption by industry [2]. For example, only 12.5% of Horizon 2020's consortia members were from the industry despite its powerful funding instrument for participation [101].

Nevertheless, OI approaches have been successfully applied in RAI. For example, in the pharmaceutics sector for orchestrating drug discovery (MELLODY),[4] which includes GlaxoSmithKline (GSK), Merck, and Novartis [1]. Combined with blockchain technology, MELLODY enables traditional competitors to share their data about specific drug compounds without losing their intellectual property [214]. It is a prime example of OI in new product development as organizations respond to increasing globalization, technological complexity, intensified competition, and scarce resources [215,216]. In MELLODY's case, large data sets are protected under privacy laws and blockchain provides the underlying technology for enabling governance. Another novel OI project conducts a crowdsourced RAI audit whereby individuals sign up for a tool to indicate their perception of bias and fairness of AI systems [217]. AI-centric innovation (eco-)systems are also flourishing in the banking and financial services sectors where symbiotic relationships are being formed between fintech companies, banks, and payment providers [19,53]. Digital trading applications are an example of emerging OI in that sector [218].

5.4. *Sustainability*

The ISO26000:2010 standard expands CSR to social responsibility for organizations of all sizes (i.e., beyond corporates) with the ultimate objective of sustainability [219]. The standard defines 'core subjects' that rely on *organizational* governance for their implementation: stakeholder engagement, consumer issues, the environment, human rights, labor practices, and equal operating practices [220]. This interrelationship of sustainability with other RI themes can also be seen in Fig. 7, which shows a strong thematic connection between sustainability; stakeholder engagement; and governance, regulation, and policy. According to Zhao [221], sustainability in RAI is seen mainly in a robotics context with influence from ethical principles, which is also illustrated by Fig. 9.

5.4.1. *Adaptive socially responsible governance*

The problem with ISO26000 is that it is purely a guideline and not a management standard with certifying bodies [222]. Today's reality is that an organization's governance drives toward profitability objectives (i.e., economic sustainability) often overriding social responsibilities [66,223]. Here is where the importance of stakeholder engagement comes to play for RI implementation in an *adaptive* governance process whereby government and stakeholders share public and private resources to co-produce policy [224]. The idea of engaging citizens in adaptive governance dates back to Kaufman's concept in 1960 of a "participatory democracy", which involves public stakeholders as managers of public affairs through joint discussion and negotiation [225]. When sustainability is added to 'ethical governance' (see Section 5.2 Governance, Regulation, and Policy), it leads to the term 'socially responsible governance'.

The question of whether AI could act more socially responsible than humans is intriguing. Krkač [226] posits that AI may be "less irresponsible" than humans. However, sustainability is underrepresented in public RAI declarations [103] and scholarly publications which can be seen by its small sphere size (weight) in Fig. 12c).

5.4.2. *Technology assessment and foresight*

The triangle in Fig. 12c) also depicts that TAF methods are an emerging theme in RAI as a driver toward social responsibility. This is encouraging because Fig. 9 reveals a current methods gap in RAI. TAF and RI are intertwined to the extent that some authors describe RI as an 'extension of TAF' for developing socially responsible principles and practices that rely on applied ethics, STS, and governance [5,108,227]. However, TAF has progressed independently from RI to embrace early stakeholder engagement and evaluation with

[4] Machine Learning Ledger Orchestration for Drug Discovery.

ethics [6,78]. This evolutionary progress for TAF can be seen in Fig. 7. In any case, RI is more than TAF, because it includes ex-ante (future-oriented) TAF methods and ex-post (experienced) impact by society [101,107] as shown in Fig. 11b).

5.4.3. RAI tools innovation subsystem

The adoption of TAF by RAI has been slow as industry and NGOs have recently created an abundance of software tools to fill the methods gap in RAI [28,228]. Gartner, a global analyst, and consultancy firm, regularly publishes reports about such tools [229]. In their "magic quadrant" report on data science and machine learning, they assessed 20 vendors of algorithmic development platforms, which includes sourcing data, building models, and operationalizing algorithmic AI. The report suggests that RAI transparency, addressing model-based biases, and governance are the most valuable differentiators in the market. It was found that all assessed vendors are finally making progress in these areas [230]. But there is skepticism as to whether such progress genuinely addresses the ethics of social responsibility [3,202,231] as the industry is still overhyping AI developments [232,233]. Comparisons across the industry to gauge commitment to sustainability are difficult because their RI declarations have organization-specific jargon and varying areas of focus [234–237]. For example, Facebook/Meta lists the following focal areas for its RI approach: autonomy, civic engagement, constructive discourse, economic security, environmental sustainability, fairness and inclusion, privacy and data protection, safety, voice, and well-being [238].

5.5. A framework for the adoption of responsible innovation by responsible artificial intelligence

A synthesis of the findings in Section 5 enabled the abductive development of a *theoretical framework for the adoption of RI along RAI's 'axis of adoption'*. This framework is depicted in Fig. 13 as a causal loop diagram.

Causal loop diagrams have been developed in RI-related research to model socio-technical phenomena [239], technology sustainability [240], or innovation systems [241]. The '+' signs in Fig. 13 denote a reinforcing impact and the '-' signs signify a reversing impact. Three future phases are depicted. The left-hand side of Fig. 13 starts in Phase 1 with the impetus of the EU's imminent RAI regulation on socially responsible governance and its open science policy on stakeholder engagement. Following this first phase, the right-hand side depicts a second phase that enables organizational RAI governance in practice to meet the EU's regulatory requirements through processes, structures, methods, and tools. TAF has already established itself as a mature way to engage citizens and organizations in RI governance and is likely to be more widely deployed in RAI in the second phase to anticipate unintended (and intended) consequences. A wealth of free and commercial tools on vendor platforms is already emerging today. This tools innovation subsystem will become mature enough in the second phase to address the principles-to-practice gap. However, a degree of standardization will be required for a tools innovation system to prosper. Such standardization requires:

(1) a more *consistent conceptualization of ethical RAI principles* than the status quo;
(2) broader *integration of global ethics* than the current Eurocentric RI views; and
(3) agreement on processes and structures for *organizational RAI governance.*

Fig. 13 reveals that the issue of RI adoption by RAI is at the intersection of the above three points. Here is where the current impasse is, and it is posited that stakeholder engagement of citizens from diverse cultures across the Global North and South is a *policy leverage point* for moving the RI adoption by RAI toward a third, global best practice phase as shown in the center of Fig. 13.

5.6. Implications for managerial practice

Jaworski defines managerial relevance as "the degree to which a specific manager in an organization perceives academic knowledge to aid his or her job-related thoughts or actions in the pursuit of organizational goals" [242]. The author argues that "role-relevant research" is a requirement for a meaningful impact in managerial practice. This implies a thorough understanding of "a particular role in the organization" and selecting "a specific route to impact for a particular executive". In RAI, it is increasingly recognized that AI designers and developers need to be accountable for unintended consequences [79,180,191]. To address a specific route for managerial role impact, a documented planning process for AI algorithms has been proposed, which puts the accountability for their ethical behavior on the AI designers and developers [243]. Another proposal goes even further and includes accountability for the delegation of roles and responsibilities [188].

The extant literature on RAI is immature in addressing other role-relevant research and focuses on more abstract stakeholder roles as discussed in this research. In a similar case where role-relevant research was not identifiable, Salminen et al. proposed to focus on 1) the impact and timing of managerial implications, 2) knowledge needs for implications (e.g., empirical findings, concepts, frameworks, theory, processes, etc.), and 3) a typology of managerial tasks (e.g., strategist, coordinator, controller, transformer, etc.) [244]. As this research was a cross-disciplinary review of two fields toward their convergence, its managerial *impact* is transformational and the *timing* has been modeled in three phases in Fig. 13. The *knowledge needs for practical implications* have been discussed extensively in Section 5 in terms of inconsistent conceptualizations of ethical principles, Eurocentric ethical norms, government regulation, a principles-to-practice gap, organizational governance processes and structures, citizen engagement, university and NGO engagement, open science, open innovation, adaptive socially responsible governance, TAF, and the RAI tools innovation subsystem.

In a *typology of managerial tasks*, strategy is a paramount task in Phase 1 of Fig. 13. Phase 2 will be transformational. Phase 3 is likely to be less transformational and involves continuous improvement. In that phase, it was found that stakeholder engagement is a leverage point for *policy makers*, which involves citizens from diverse cultures across the Global North and South. However,

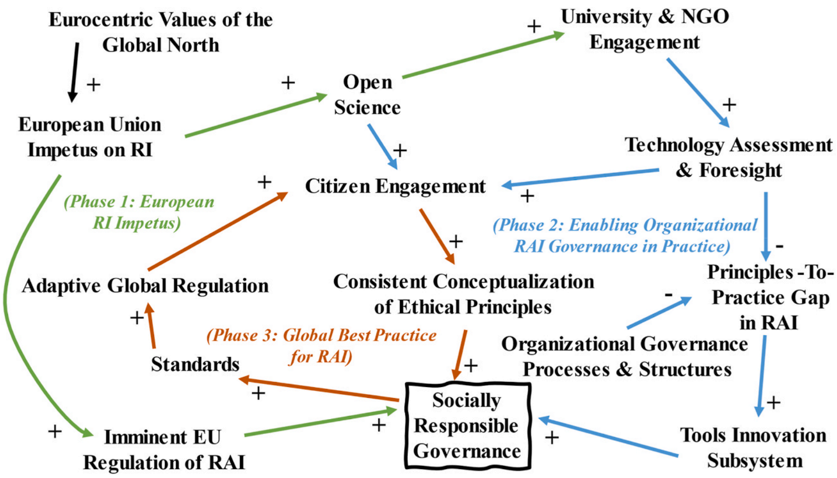

Fig. 13. A framework for the adoption of responsible innovation by responsible artificial intelligence (source: author).

involvement of the Global South must not be an afterthought that is relegated to Phase 3 in the future. Arun points out risks of "discrimination, bias, oppression, exclusion, and bad design", which "can be exacerbated in the context of vulnerable populations, especially those without access to human rights law or institutional remedies" [245]. This study raises policy makers' awareness of the current underrepresentation of the Global South in RAI and proposes that policy makers empower Southern populations through inclusion in policy making. This needs to occur now to avoid the risk of harming vulnerable populations.

6. Conclusions, limitations, and suggestions for future research

The diffusion of AI in industry occurs at a rapid pace and is also deeply embedded in consumers' lives through social media and home automation. RI has a longer history, but its uptake by RAI has been slow as RAI captured the imagination of academics and practitioners alike with three times the number of publications than RI. However, as this research has shown, the scholarly RAI literature is fragmented, organizational RAI governance in industry is inconsistent, a gap exists in operationalizing ethical principles in practice, and emerging tools need time to mature.

This research contributes theoretical knowledge and addresses the knowledge needs of practitioners through its discovery of an emerging 'axis of RI adoption' comprised of ethics, governance, stakeholder engagement, and sustainability as fundamental constructs. From these constructs, a theoretical framework was developed in Fig. 13 to predict the adoption of RI by RAI in three phases. The managerial implications in Phase 1 are strategic, Phase 2 is transformational, and Phase 3 is continuous improvement. The extant literature provides role-specific recommendations only for *AI designers and developers*. This study adds a role-specific call to action for *policy makers* to involve citizens from diverse cultures of the Global South to avoid the risk of harming vulnerable populations.

Employing *systematic science mapping* as a new method, this research also makes a methodological contribution by bibliographically mapping 2489 articles for RAI and 828 articles for RI from the Scopus database. A review of extant literature reviews in Section 2.4 demonstrated that this research is the largest systematic literature review of both fields and the only cross-disciplinary review between both fields to date.

A *limitation* of this research is acknowledged as Google Scholar (the largest bibliometric database) was used in the literature review of Section 2, but it could not be used for systematic science mapping in Section 3 due to its lack of bulk export capability. WoS does not cover as much variety of journals as Scopus and most AI-related publications outside WoS are covered in Scopus. These considerations led to the reliance on Scopus for the quantitative results. A further limitation of this research is that articles outside the parameter thresholds of Table 3 were not included in the science mapping results. This is always a limitation in science mapping and therefore, its parameters are usually varied iteratively to maximize the inclusion of articles. For RI, 77% of the 828 Scopus articles were mapped in the evolutionary map of Fig. 7. This percentage may be referred to as a 'mapping factor'. Unfortunately, this mapping factor is rarely reported in science mapping studies. For RAI, only 30% of the 2489 articles were included in Fig. 9. No parameter combination was found to increase that factor beyond 30% in a meaningful visualization. This reflects an RAI literature fragmented by jargon with substantial overlaps and variance across concepts as discussed in Section 5.1 Ethics. For example, the year 2020 in Fig. 10 contains about eight times the number of RAI keywords as compared to RI in Fig. 8, which corroborates RAI's fragmentation quantitatively. One way to overcome this fragmentation for a larger mapping factor is to perform a curation of the RAI articles' keywords to align every article's themes toward common RAI denominators. In a separate research project, Herrmann [85] uses a mixed-methods research design to combine science mapping with a qualitative curation of all articles' keywords toward common denominators. The mapping factor then doubled to 63%. But the average h-index dropped from 14 to 9, meaning that less impactful articles diluted the overall quality of the result. Again, this reinforces the fragmentation of the RAI literature.

The constructs and relationships in Fig. 13 have been discussed and validated in Section 5 (Discussion and Synthesis of Results) from both a theoretical as well as a practice perspective.

An area of *future research* would be the empirical validation of the causal loop framework, built from these components, when the three phases unfold in the future. Another area of future research would be the application of AI to the RI-based innovation process itself. For example, to identify specific stakeholders, given the importance of engaging citizens, universities, and NGOs as per the causal loops shown in Fig. 13. Finally, the extant RAI literature lacks role-specific recommendations for actionable impact in management practice. A thorough study of practitioner job roles in the RAI field would enable specific recommendations that directly impact practice.

Author contribution statement

Heinz Herrmann: Conceived and designed the research methodology (systematic science mapping), gathered the data, conducted the cross-disciplinary analysis, syntesized the cross-disciplinary analysis into a causal loop diagram, and wrote the paper.

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The data included in this article and Boolean search terms for its replication were provided in the text.

Declaration of interest's statement

The author declares no conflict of interest.

References

[1] N. Benaich, I. Hogarth, State of AI Report, 2020. London, UK.
[2] T. Brand, V. Blok, Responsible innovation in business, J. Responsible Innov. 6 (1) (2019) 4–24.
[3] A. Gurzawska, Responsible innovation in business, Sustainability 13 (4) (2021) 1826.
[4] V. Blok, P. Lemmens, The emerging concept of responsible innovation, in: Responsible Innovation 2, Springer, 2015, pp. 19–35.
[5] E. Fisher, Entangled futures and responsibilities in technology assessment, J. Responsible Innov. 4 (2) (2017) 83–84.
[6] A. Grunwald, Technology assessment for responsible innovation, in: J. van den Hoven (Ed.), Responsible Innovation 1, Springer, Dortrecht, The Netherlands, 2014, pp. 15–31.
[7] D.H. Guston, et al., Responsible innovation: motivations for a new journal, J. Responsible Innov. 1 (1) (2014) 1–8.
[8] H. Webb, et al., A responsive engagement approach to promote the development of 'Fairer'Algorithms, in: ECIAIR 2019, Academic Conferences & Publishing, Oxford, UK, 2019.
[9] R. Owen, M. Pansera, Responsible innovation and responsible research and innovation, in: D. Simon (Ed.), Handbook on Science and Public Policy, Edward Elgar, Cheltenham, UK, 2019, pp. 26–48.
[10] M. Brundage, Artificial intelligence and responsible innovation, in: V. Müller (Ed.), Fundamental Issues of Artificial Intelligence, Springer, New York, USA, 2016, pp. 543–554.
[11] M. Jirotka, et al., Responsible research and innovation in the digital age, Commun. ACM 60 (5) (2017) 62–68.
[12] H. Bennink, Understanding and managing responsible innovation, Philos. Manag. 19 (3) (2020) 317–348.
[13] H. Jamali, G. Azadi-Ahmadabadi, S. Asadi, Interdisciplinary relations of converging technologies, Scientometrics 116 (2) (2018) 1055–1073.
[14] H. Herrmann, The arcanum of artificial intelligence in enterprise applications: toward a unified framework, J. Eng. Technol. Manag. 66 (Oct-Dec 2022) 101716.
[15] S.J. Russell, P. Norvig, Artificial Intelligence: A Modern Approach, 4 ed, Prentice Hall, Englewood Cliffs, N.J, 2020.
[16] E. Glikson, A.W. Woolley, Human trust in artificial intelligence: review of empirical research, Acad. Manag. Ann. 14 (2) (2020) 627–660.
[17] M. Haenlein, A. Kaplan, Artificial intelligence and robotics, J. Bus. Res. 124 (2021) 405–407.
[18] Daugherty, P. Are you ready for what's next? 2019; Available from: https://www.accenture.com/us-en/insights/technology/new-emerging-technologies-darq.
[19] H. Herrmann, B. Masawi, Three and a half decades of artificial intelligence in banking, financial services, and insurance: a systematic evolutionary review, Strat. Change 31 (6) (2022) 549–569.
[20] N. van Eck, L. Waltman, Software survey: VOSviewer, a computer program for bibliometric mapping, Scientometrics 84 (2) (2010) 523–538.
[21] A.E. Nielsen, C. Thomsen, Corporate social responsibility (CSR) management and marketing communication: research streams and themes, HERMES – Journal of Language and Communication in Business 25 (49) (2017) 49.
[22] N. Comerio, F. Strozzi, Tourism and its economic impact: a literature review using bibliometric tools, Tourism Econ. 25 (1) (2019) 109–131.
[23] M. Taddeo, L. Floridi, How AI can be a force for good, Science 361 (6404) (2018) 751–752.
[24] Y. Wang, M. Xiong, H. Olya, Toward an understanding of responsible artificial intelligence practices, in: Proceedings of the 53rd Hawaii International Conference on System Sciences, Hawaii International Conference on System Sciences (HICSS), 2020.
[25] European Union. Proposal for a regulation of the European parliament and tof the council laying down harmonised rules on artificial intelligence. 2021 31 Aug 2021]; Available from: https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1623335154975&uri=CELEX%3A52021PC0206.
[26] K. Amunts, et al., The human Brain project: Creating a European research Infrastructure to Decode the human Brain, Neuron 92 (3) (2016) 574–581.
[27] V. Müller, Ethics of Artificial Intelligence and Robotics, in: E. Zalta (Ed.), The Stanford Encyclopedia of Philosophy, The Metaphysics Research Lab, Stanford, CA, USA, 2021.
[28] Schiff, D., et al., Principles to practices for responsible AI. arXiv preprint arXiv:2006.04707, 2020.
[29] B. Shneiderman, Human-centered artificial intelligence: three Fresh ideas, AIS Trans. Hum.-Comput. Interact. 12 (3) (2020) 109–124.
[30] L. Vesnic-Alujevic, S. Nascimento, A. Pólvora, Societal and ethical impacts of artificial intelligence, Telecommun. Pol. 44 (6) (2020) 101961.
[31] 360 Research Reports. Global Enterprise AI Market Size, Share - Segmented by Offering, Deployment, Technology, End-user Industry, and Region - Growth, Trends, and Forecast (2018–2023). 2018 2 September 2020]; Available from: https://www.360researchreports.com/global-enterprise-ai-market-13104627.
[32] D. Li, T.W. Tong, Y. Xiao, Is China Emerging as the Global Leader in AI? Harvard Business Review, 2021.
[33] N. Smuha, From a 'race to AI'to a 'race to AI regulation'. Law, Innovation and Technology 13 (1) (2021) 57–84.

[34] TechNavio. Global Enterprise AI Market 2018–2022, 2018 2 September 2020], Available from: https://www.researchandmarkets.com/reports/4613309/global-enterprise-ai-market-2018-2022.
[35] Verified Market Research. Enterprise AI Market Size, Share, Trends, Opportunities & Forecast. 2020 2 September 2020]; Available from: https://www.verifiedmarketresearch.com/product/enterprise-ai-market/.
[36] A. Richards, TikTok. Critical Reflections, 2021.
[37] H. Roberts, et al.. The Chinese approach to artificial intelligence: an analysis of policy and regulation, AI & SOCIETY (36), 2021, pp. 59–77.
[38] Standards Administration of China. White Paper on Artificial Intelligence Standardization. 2018 2 April 2020]; Available from: https://www.newamerica.org/cybersecurity-initiative/digichina/blog/translation-excerpts-chinas-white-paper-artificial-intelligence-standardization/.
[39] H. Fitsch, et al., Coalition-making and the practice of feminist STS in the time of COVID-19. Catalyst: feminism, theory, Technoscience 6 (2) (2020).
[40] Moyer, E. Facebook privacy lawsuit over facial recognition leads to $650M settlement. 2021 17 March 2021]; Available from: https://www.cnet.com/news/facebook-privacy-lawsuit-over-facial-recognition-leads-to-650m-settlement/.
[41] M. Luengo-Oroz, Solidarity should be a core ethical principle of AI, Nat. Mach. Intell. 1 (11) (2019) 494.
[42] V. Bhargava, M. Velasquez, Ethics of the attention economy, Bus. Ethics Q. 31 (3) (2021) 321–359.
[43] Leprince-Ringuet, D. Ex-Google engineer: Extreme content? 2019 17 April 2021]; Available from: https://www.zdnet.com/article/ex-youtube-engineer-extreme-content-no-its-algorithms-that-radicalize-people/.
[44] T. King, et al., Artificial intelligence crime, Sci. Eng. Ethics 26 (1) (2020) 89–120.
[45] Darktrace. AI-Augmented Attacks and the Battle of the Algorithms. 2021; Available from: https://static.cbsileads.com/direct/whitepapers/AI-Augmented_Attacks_and_the_Battle_of_the_Algorithms_(2).pdf.
[46] Grey, C. and N. Mitev, *Re-engineering organizations*. Person. Rev., 1995. 24(1): p. 6–18.
[47] M. Santana, M.J. Cobo, What is the future of work? A science mapping analysis, Eur. Manag. J. 38 (6) (2020) 846–862.
[48] World Bank. The changing nature of work. World development report 2019 18 August 2021]; Available from: https://documents1.worldbank.org/curated/en/816281518818814423/2019-WDR-Report.pdf.
[49] Szczepanski, M. Economic impacts of artificial intelligence. European Parliamentary Research Service 2019 18 August 2021]; Available from: https://www.europarl.europa.eu/RegData/etudes/BRIE/2019/637967/EPRS_BRI(2019)637967_EN.pdf.
[50] V. Müller, N. Bostrom, Future Progress in artificial intelligence, in: Fundamental Issues of Artificial Intelligence, Springer, 2016, pp. 555–572.
[51] L. Floridi, Distributed morality in an information society, Sci. Eng. Ethics 19 (3) (2013) 727–743.
[52] Yampolskiy, R. and M. Spellchecker, Artificial Intelligence Safety and Cybersecurity. Preprint arXiv:1610.07997, 2016.
[53] A. Ashta, H. Herrmann, Artificial intelligence and fintech: an overview of opportunities and risks for banking, investments, and microfinance, Strat. Change 30 (3) (2021) 211–222.
[54] P. Bedué, A. Fritzsche, Can we trust AI? An empirical investigation of trust requirements and guide to successful AI adoption, J. Enterprise Inf. Manag. 35 (2) (2021) 530–549.
[55] G. Cao, et al., Understanding managers' attitudes and behavioral intentions towards using artificial intelligence for organizational decision-making, Technovation 106 (2021) 102312.
[56] National Security Commission on Artificial Intelligence. Final Report. 2021 4 January 2023]; Available from: https://www.nscai.gov/2021-final-report/.
[57] McKendrick, J. Preparing for the 'golden age' of artificial intelligence and machine learning. 2021 10 October 2021]; Available from: https://www.zdnet.com/article/preparing-for-the-golden-age-of-artificial-intelligence-and-machine-learning/?ftag=TRE6a12a91&bhid=%7B%24external_id%7D&mid=%7B%24MESSAGE_ID%7D&cid=%7B%24contact_id%7D&eh=%7B%24CF_emailHash%7D.
[58] Rainie, L., J. Anderson, and E.A. Vogels. Experts Doubt Ethical AI Design Will Be Broadly Adopted as the Norm Within the Next Decade. 2021 23 June 2021]; Available from: https://www.pewresearch.org/internet/2021/06/16/experts-doubt-ethical-ai-design-will-be-broadly-adopted-as-the-norm-within-the-next-decade/.
[59] L. Floridi, AI and its new winter: from myths to realities, Philos. Technol. 33 (1) (2020) 1–3.
[60] C. Milana, A. Ashta, Artificial intelligence techniques in finance and financial markets, Strat. Change 30 (3) (2021) 189–209.
[61] E. Strickland, The turbulent past and uncertain future of AI, IEEE Spectrum 58 (10) (2021) 26–31.
[62] J. Berryhill, et al., Hello, World: Artificial Intelligence and its Use in the Public Sector, OECD, Paris, France, 2019.
[63] B.M. Cole, P.M. Banerjee, Morally contentious technology-field intersections: the case of biotechnology in the United States, J. Bus. Ethics 115 (3) (2013) 555–574.
[64] C. Gonzales-Gemio, C. Cruz-Cázares, M. Parmentier, Responsible innovation in SMEs, Sustainability 12 (24) (2020) 10232.
[65] A. Wilkinson, M. Hill, P. Gollan, The sustainability debate, Int. J. Oper. Prod. Manag. 21 (12) (2001) 1492–1502.
[66] A. Scherer, C. Voegtlin, Corporate governance for responsible innovation, Acad. Manag. Perspect. 34 (2) (2020) 182–208.
[67] European Commission, Horizon Europe. 2021: Brussels, Belgium.
[68] European Commission, Horizon 2020. 2011, Technical Report: Brussels, Belgium.
[69] K. McElhaney, A strategic approach to corporate social responsibility, Leader Leader 52 (2009) 30–36.
[70] J. Stilgoe, R. Owen, P. Macnaghten, Developing a framework for responsible innovation, Res. Pol. 42 (9) (2013) 1568–1580.
[71] P. Lehoux, et al., What health system challenges should responsible innovation in health address? Int. J. Health Pol. Manag. 8 (2) (2019) 63.
[72] M. Steen, Slow innovation: the need for reflexivity in responsible innovation (RI), J. Responsible Innov. (2021) 1–7.
[73] S. Jasanoff, Designs on Nature, Princeton University Press, Princeton, USA, 2011.
[74] C. Åsberg, N. Lykke, Feminist Technoscience Studies, Sage Publications Sage UK, London, England, 2010.
[75] S. Cho, K.W. Crenshaw, L. Mccall, Toward a field of intersectionality studies: theory, applications, and praxis, Signs 38 (4) (2013) 785–810.
[76] C. D'Ignazio, L.F. Klein, Data Feminism, MIT Press, Cambridge, MA, USA, 2020.
[77] K. Bolz, A. De Bruin, Responsible innovation and social innovation, Int. J. Soc. Econ. 46 (6) (2019) 742–755.
[78] A. Grunwald, M. Achternbosch, Technology assessment and approaches to early engagement, in: N. Doorn (Ed.), Early Engagement and New Technologies: Opening up the Laboratory, Springer, Dortrecht, The Nethrelands, 2013, pp. 15–34.
[79] H. Kwon, Y. Park, Proactive development of emerging technology in a socially responsible manner: data-driven problem solving process using latent semantic analysis, J. Eng. Technol. Manag. 50 (2018) 45–60.
[80] M. Dabić, et al., 40 years of excellence: an overview of Technovation and a roadmap for future research, Technovation 106 (2021) 102303.
[81] U. Moschini, et al., A comparison of three multidisciplinarity indices based on the diversity of Scopus subject areas of authors' documents, their bibliography and their citing papers, Scientometrics 125 (2) (2020) 1145–1158.
[82] M.J. Grant, A. Booth, A typology of reviews: an analysis of 14 review types and associated methodologies, Health Inf. Libr. J. 26 (2) (2009) 91–108.
[83] J.M. Alonso, C. Castiello, C. Mencar, A bibliometric analysis of the explainable artificial intelligence research field, in: International Conference on Information Processing and Management of Uncertainty in Knowledge-Based Systems, Springer, Cádiz, Spain, 2018.
[84] A. Darko, et al., Artificial intelligence in the AEC industry: scientometric analysis and visualization of research activities, Autom. ConStruct. 112 (2020) 103081.
[85] Herrmann, H., Introducing the Systematic Science Mapping Framework: an innovative and mixed approach for macro scale reviews, in: Cameron R. Golenko X. (Eds.) Handbook of Mixed Methods Research in Business and Management, Edward Elgar, Cheltenham, UK, 2023, chapter 24.
[86] G. Aparicio, T. Iturralde, A. Maseda, Conceptual structure and perspectives on entrepreneurship education research, Eur. Res. Manag. Bus. Econ. 25 (3) (2019) 105–113 (In Print).
[87] M. Gutiérrez-Salcedo, et al., Some bibliometric procedures for analyzing and evaluating research fields, Appl. Intell. 48 (5) (2018) 1275–1287.
[88] D. Gough, S. Oliver, J. Thomas, Learning from Research, Nesta, London, UK, 2013.
[89] M.K. Linnenluecke, M. Marrone, A.K. Singh, Conducting systematic literature reviews and bibliometric analyses, Aust. J. Manag. 45 (2) (2020) 175–194.

[90] A. Castleberry, A. Nolen, Thematic analysis of qualitative research data: is it as easy as it sounds? Curr. Pharm. Teach. Learn. 10 (6) (2018) 807–815.
[91] S. Fosso Wamba, et al., Are we preparing for a good AI society? Technol. Forecast. Soc. Change 164 (2021) 120482.
[92] T. Obradović, B. Vlačić, M. Dabić, Open innovation in the manufacturing industry, Technovation 102 (2021) 102221.
[93] B. Stahl, et al., Artificial intelligence for human flourishing, J. Bus. Res. 124 (2021) 374–388.
[94] O. Granstrand, M. Holgersson, Innovation ecosystems: a conceptual review and a new definition, Technovation 90–91 (2020) 102098.
[95] B. Harsanto, et al., Responsible research and innovation (RRI) in emerging economies: a preliminary review, in: 2020 IEEE International Conference on Engineering, Technology and Innovation (ICE/ITMC), IEEE, 2020.
[96] L. Nazarko, Responsible research and innovation in enterprises, J. Open Innov. 6 (1) (2020) 14–26.
[97] M. Kuc-Czarnecka, M. Olczyk, How ethics combine with big data, Humanit. Soc. Sci. Commun. (1) (2020) 7.
[98] A. Di Vaio, et al., Artificial intelligence and business models in the sustainable development goals perspective, J. Bus. Res. 121 (2020) 283–314.
[99] J. Hernández-Orallo, K. Vold, AI extenders, in: 24th European Conference on Artificial Intelligence (ECAI 2020), Santiago de Compostela, Spain, 2020.
[100] M. Loi, C. Heitz, M. Christen, A comparative assessment and synthesis of twenty ethics codes on AI and big data, in: 2020 7th Swiss Conference on Data Science (SDS), IEEE, 2020.
[101] L. Nazarko, Responsible research and innovation, Bus. Theor. Pract. 20 (2019) 342–351.
[102] V. Vakkuri, P. Abrahamsson, The key concepts of ethics of artificial intelligence, in: 2018 IEEE International Conference on Engineering, Technology and Innovation (ICE/ITMC), IEEE, 2018.
[103] A. Jobin, M. Ienca, E. Vayena, The global landscape of AI ethics guidelines, Nat. Mach. Intell. 1 (9) (2019) 389–399.
[104] B. Tran, et al., Global evolution of research in artificial intelligence in health and Medicine, J. Clin. Med. 8 (3) (2019) 360.
[105] A. Ronzhyn, M. Wimmer. Literature review of ethical concerns in the use of disruptive technologies in government 3.0, ICDS, 2019, pp. 85–93.
[106] O. Zawacki-Richter, et al., Systematic review of research on artificial intelligence applications in higher education, Int. J. Educ. Technol. High. Educ. 16 (1) (2019) 1–27.
[107] W. Reijers, et al., Methods for practising ethics in research and innovation, Sci. Eng. Ethics 24 (5) (2018) 1437–1481.
[108] M. Burget, E. Bardone, M. Pedaste, Definitions and conceptual dimensions of responsible research and innovation: a literature review, Sci. Eng. Ethics 23 (1) (2017) 1–19.
[109] R. Lubberink, et al., Lessons for responsible innovation in the business context, Sustainability 9 (5) (2017) 721.
[110] R. Heersmink, et al., Bibliometric mapping of computer and information ethics, Ethics Inf. Technol. 13 (3) (2011) 241–249.
[111] A. Di Vaio, et al., Responsible innovation and ethical corporate behavior in the Asian fashion industry: a systematic literature review and avenues ahead, Asia Pac. J. Manag. (2022). https://link.springer.com/article/10.1007/s10490-022-09844-7#citeas.
[112] A.A. Chadegani, et al., A comparison between two main academic literature collections: web of science and Scopus databases, Asian Soc. Sci. 9 (5) (2013) 18–26.
[113] P. Mongeon, A. Paul-Hus, The journal coverage of Web of science and Scopus, Scientometrics 106 (1) (2016) 213–228.
[114] J.L. Ruiz-Real, et al., Artificial intelligence in business and economics research: trends and future, J. Bus. Econ. Manag. (2020) 1–20.
[115] A.-W. Harzing, S. Alakangas, Google scholar, scopus and the web of science: a longitudinal and cross-disciplinary comparison, Scientometrics 106 (2) (2016) 787–804.
[116] A. Martín-Martín, et al., Google scholar, web of science, and scopus: a systematic comparison of citations in 252 subject categories, Journal of Informetrics 12 (4) (2018) 1160–1177.
[117] M. Cobo, et al., Science mapping software tools, J. Am. Soc. Inf. Sci. Technol. 62 (7) (2011) 1382–1402.
[118] A. Martín-Martín, et al., Google scholar, microsoft academic, scopus, dimensions, Web of science, and OpenCitations' COCI, Scientometrics 126 (1) (2021) 871–906.
[119] M.A. Martínez, et al., Analyzing the scientific evolution of social work using science mapping, Res. Soc. Work. Pract. 25 (2) (2015) 257–277.
[120] V. Silber-Varod, Y. Eshet-Alkalai, N. Geri, Culturomics: reflections on the potential of big data discourse analysis methods for identifying research trends, Online Journal of Applied Knowledge Management (OJAKM) 4 (1) (2016) 82–98.
[121] W. Glänzel, H.F. Moed, Opinion paper: thoughts and facts on bibliometric indicators, Scientometrics 96 (1) (2013) 381–394.
[122] J. Fjeld, et al., Principled Artificial Intelligence, Berkman Klein Center, 2020.
[123] H. Nelson, Foreword, in: J. Liebowitz (Ed.), Data Analytics & AI, Taylor & Francis, Boca Raton, 2021, pp. ix–xv.
[124] L. Floridi, Translating principles into practices of digital ethics: five risks of being unethical, Philos. Technol. 32 (2019) 185–193.
[125] E. Hechler, M. Oberhofer, T. Schaeck, Deploying AI in the Enterprise, Apress, NY, USA, 2021.
[126] J. Piorkowski, Unraveling data science, artificial intelligence and autonomy, in: J. Liebowitz (Ed.), Data Analytics & AI, Taylor & Francis, Boca Raton, 2020.
[127] A. Sestino, A. De Mauro, Leveraging artificial intelligence in business: implications, applications and methods, Technol. Anal. Strat. Manag. (2021) 1–14.
[128] J.H. Littell, Meta-analysis, in: Encyclopedia of Social Work, 2013.
[129] A. Sartal, M. González-Loureiro, X.H. Vázquez, Meta-analyses in management: what can we learn from clinical research? BRQ Business Research Quarterly 24 (1) (2021) 91–111.
[130] L. Alcaide–Muñoz, et al., Analysing the scientific evolution of e-Government using a science mapping approach, Govern. Inf. Q. 34 (3) (2017) 545–555.
[131] S. Batistič, P. van der Laken, History, Evolution and Future of big Data and analytics, Br. J. Manag. 30 (2) (2019) 229–251.
[132] Leydesdorff, L. and S. Milojević, Scientometrics. arXiv preprint arXiv:1208.4566, 2012.
[133] M. Ben-Daya, E. Hassini, Z. Bahroun, Internet of things and supply chain management: a literature review, Int. J. Prod. Res. 57 (15–16) (2019) 4719–4742.
[134] L. Shamseer, et al., Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015: elaboration and explanation, BMJ 350 (jan02 1) (2015) g7647.
[135] H. Adnani, M. Cherraj, H. Bouabid, Similarity indexes for scientometric research: a comparative analysis, Malays. J. Libr. Inf. Sci. 25 (3) (2020) 31–48.
[136] M. Callon, W.A. Turner, From translations to problematic networks: an introduction to co-word analysis, Soc. Sci. Inf. 22 (2) (1983) 191–235.
[137] S. Kumar, N. Pandey, A. Haldar, Twenty years of public management review (PMR), Publ. Manag. Rev. 22 (12) (2020) 1876–1896.
[138] A. Mas-Tur, et al., Half a century of quality & quantity, Qual. Quantity 53 (2) (2019) 981–1020.
[139] V. Vakkuri, K.-K. Kemell, P. Abrahamsson, Ethically aligned design, in: 2019 45th Euromicro Conference on Software Engineering and Advanced Applications (SEAA), IEEE, 2019.
[140] C. Sternitzke, I. Bergmann, Similarity measures for document mapping: a comparative study on the level of an individual scientist, Scientometrics 78 (1) (2009) 113–130.
[141] N. van Eck, L. Waltman, How to normalize cooccurrence data? J. Am. Soc. Inf. Sci. Technol. 60 (8) (2009) 1635–1651.
[142] A. Mas-Tur, et al., Advances in management research, Rev. Manag. Sci. 14 (5) (2020) 933–958.
[143] M. Decker, et al., Imagined technology futures in demand-oriented technology assessment, J. Responsible Innov. 4 (2) (2017) 177–196.
[144] H. Kwon, J. Kim, Y. Park, Applying LSA text mining technique in envisioning social impacts of emerging technologies, Technovation 60–61 (2017) 15–28.
[145] K. Cuhls, Horizon scanning in foresight, Futures Foresight Sci. (1) (2020) 2.
[146] National Academies of Sciences, Horizon scanning and foresight methods, in: Safeguarding the Bioeconomy, National Academies Press, Washington, DC, USA, 2020.
[147] J. Buehring, J. Liedtka, Embracing systematic futures thinking at the intersection of Strategic Planning, Foresight and Design Journal of Innovation Management 6 (3) (2018) 134–152.
[148] J. Rincon-Patino, G. Ramirez-Gonzalez, J.C. Corrales, Exploring machine learning: a bibliometric general approach using SciMAT, F1000Research 7 (May) (2018) 1–21.
[149] E. Hackett, Politics and publics, in: E. Hackett (Ed.), The Handbook of Science and Technology Studies, MIT Press, Cambridge, MA, USA, 2008, pp. 429–432.
[150] B. Balázs, J. Horváth, G. Pataki, Science-society dialogue from the start, Eur. J. Futures Res. (1) (2020) 8.

[151] T. Okedi, A. Fisher, Time series analysis and long short-term memory (LSTM) network prediction of BPV current density, Energy Environ. Sci. 14 (4) (2021) 2408–2418.
[152] N. Wiener, The Human Use of Human Beings. Ed. 2, Rev, Doubleday Anchor Books, New York, USA, 1954.
[153] T.W. Bynum, Norbert Wiener's Vision, The impact of the Internet on our moral lives (2005) 11–25.
[154] R. Nath, V. Sahu, The problem of machine ethics in artificial intelligence, AI Soc. 35 (1) (2017) 103–111.
[155] Blackman, R. A Practical Guide to Building Ethical AI. 2020 18 March 2021]; Available from: https://hbr.org/2020/10/a-practical-guide-to-building-ethical-ai.
[156] C. Cath, et al., Artificial intelligence and the 'good society': the US, EU, and UK approach, Sci. Eng. Ethics 24 (2) (2018) 505–528.
[157] B. Mittelstadt, Principles alone cannot guarantee ethical AI, Nat. Mach. Intell. 1 (11) (2019) 501–507.
[158] U. Pagallo, Even angels need the rules: AI, roboethics, and the law, in: European Conference on Artificial Intelligence, IOS Press, The Hague, The Netherlands, 2016.
[159] Smith, G.P., Bioethics in the 21st Century: Principlism, Situation Ethics, and Love. CUA Columbus School of Law Legal Studies Research Paper, 2020(2020-2).
[160] K. Martin, Designing ethical algorithms, MIS Q. Exec. 18 (2) (2019) 129–142.
[161] S. Sun, et al., Newspaper coverage of artificial intelligence, Telematics Inf. 53 (2020) 101433.
[162] A. Buhmann, C. Fieseler, Towards a deliberative framework for responsible innovation in artificial intelligence, Technol. Soc. 64 (2021) 101475.
[163] E. Makarius, et al., Rising with the machines, J. Bus. Res. 120 (2020) 262–273.
[164] J. Guszcza, et al., Human Values in the Loop, Deloitte, NY, USA, 2021.
[165] R. Arkin, Ethics and autonomous systems, Proc. IEEE 104 (10) (2016) 1779–1781.
[166] K. Richardson, Are sex robots as bad as killing robots? in: J. Seibt, M. Nørskov, S. Schack Andersen (Eds.), What Social Robots Can and Should Do IOS Press, Amsterdam, Netherlands, 2016, pp. 27–31.
[167] T. Kubes, New materialist perspectives on sex robots, Soc. Sci. 8 (8) (2019) 224.
[168] J. Borenstein, R. Arkin, Robots, ethics, and intimacy, in: D. Berkich, M. d'Alfonso (Eds.), On the Cognitive, Ethical, and Scientific Dimensions of Artificial Intelligence, Springer, Cham, Switzerland, 2019, pp. 299–309.
[169] E. Awad, et al., The moral machine experiment, Nature 563 (7729) (2018) 59–64.
[170] D. Schiff, et al., What's next for AI ethics, policy, and governance?, in: Proceedings of the AAAI/ACM Conference on AI, Ethics, and Society, 2020.
[171] Perrault, R., et al. The AI Index. 2019 9 August 2021]; Available from: https://hai.stanford.edu/sites/default/files/ai_index_2019_report.pdf.
[172] P.S. Herzog, et al., Studying religiosity and Spirituality: a review of macro, Micro, and Meso-level approaches, Religions 11 (9) (2020) 437.
[173] J. McPhetres, et al., Reflecting on God's will: Reflective processing contributes to religious peoples' deontological dilemma responses, J. Exp. Soc. Psychol. 79 (2018) 301–314.
[174] M. Torry, Ethical religion in primary care, Lond. J. Prim. Care 9 (4) (2017) 49–53.
[175] A. Winfield, M. Jirotka, Ethical governance is essential to building trust in robotics and artificial intelligence systems, Philosophical Transactions of the Royal Society A 376 (2133) (2018) 20180085–20180098.
[176] Jaume-Palasí, L., et al. AI Ethics Guidelines Global Inventory. 2021 21 June 2019 3 April 2021]; Available from: https://algorithmwatch.org/en/ai-ethics-guidelines-global-inventory/.
[177] A. Daly, et al., Artificial intelligence, governance and ethics, in: The Chinese University of Hong Kong Faculty of Law Research Paper, 2019.
[178] European Commission. A European approach to Artificial intelligence. 2021 31 Aug 2021]; Available from: https://digital-strategy.ec.europa.eu/en/policies/european-approach-artificial-intelligence.
[179] R. Amos, et al., Privacy policies over time, Proceedings of the Web Conference (2021) 2165–2176.
[180] B. Stahl, D. Wright, Ethics and privacy in AI and big data, IEEE Secur. Priv. 16 (3) (2018) 26–33.
[181] Brundage, M., et al., Toward trustworthy AI development: mechanisms for supporting verifiable claims. arXiv preprint arXiv:2004.07213, 2020.
[182] R. Eitel-Porter, Beyond the promise: implementing ethical AI, AI and Ethics 1 (1) (2021) 73–80.
[183] P. Brey, et al., The ethical assessment of research and innovation, in: Finding Common Ground, Emerald, Bingley, UK, 2017, pp. 185–198.
[184] J. Morley, et al., From what to how, Sci. Eng. Ethics 26 (4) (2020) 2141–2168.
[185] K. Jahn, et al., more than ticking off a checklist?, in: Wirtschaftsinformatik (Community Tracks), 2020. Potsdam, Germany.
[186] C. Aicardi, M. Reinsborough, N. Rose, The integrated ethics and society programme of the Human Brain Project, J. Responsible Innov. 5 (1) (2018) 13–37.
[187] K. Amunts, et al., The human Brain project, PLoS Biol. 17 (7) (2019) e3000344.
[188] K. Martin, Ethical implications and accountability of algorithms, J. Bus. Ethics 160 (4) (2019) 835–850.
[189] N. Spencer, et al., What on earth is responsible innovation anyway?, in: Proceedings of the 19th International Conference on Engineering and Product Design Education, 2017.
[190] L. Floridi, The Logic of Information: A Theory of Philosophy as Conceptual Design, first ed., Oxford University Press, Oxford, UK, 2019.
[191] Morley, J., et al., Ethics as a service. arXiv preprint arXiv:2102.09364, 2021.
[192] Sicular, S., et al. Cool Vendors in AI Governance and Responsible AI. 2021; Available from: https://www.gartner.com/en/documents/4002446/cool-vendors-in-ai-governance-and-responsible-ai.
[193] European Union. ETHNA - The Project. 2020 16 October 2022]; Available from: https://ethnasystem.eu/about-ethna/the-project/.
[194] González-Esteban, E., et al. The ETHNA System. 2021 16 October 2022]; Available from: https://ethnasystem.eu/results/.
[195] E. González-Esteban, P. Calvo, Ethically governing artificial intelligence in the field of scientific research and innovation, Heliyon (2022) (2022) 8.
[196] H. Herrmann, R. Cameron, Responsible mixed methods research (RMMR), in: R. Cameron, X. Golenko (Eds.), Handbook of Mixed Methods Research in Business and Management, Edward Elgar, Cheltenham, UK, chapter 5, 2023 (In Print).
[197] B. Vincent, The politics of buzzwords at the interface of technoscience, market and society, Publ. Understand. Sci. 23 (3) (2014) 238–253.
[198] D. Schuurbiers, et al., Early Engagement and New Technologies, in: N. Doorn (Ed.) vol. 16, Springer, Dortrecht, The Netherlands, 2014, pp. 3–14.
[199] K. Paskaleva, I. Cooper, Open innovation and the evaluation of internet-enabled public services in smart cities, Technovation 78 (2018) 4–14.
[200] N. Haefner, et al., Artificial intelligence and innovation management: a review, framework, and research agenda, Technol. Forecast. Soc. Change 162 (2021) 120392.
[201] C. Wittrock, et al., Implementing responsible research and innovation, in: SpringerBriefs in Ethics, Open Access: Springer, 2021.
[202] D. Greene, A.L. Hoffmann, L. Stark, Better, nicer, clearer, fairer, in: Proceedings of the 52nd Hawaii International Conference on System Sciences, 2019.
[203] C. Abbot, Bridging the gap, J. Law Soc. 39 (3) (2012) 329–358.
[204] R. Owen, et al., Organisational institutionalisation of responsible innovation, Res. Pol. 50 (1) (2021) 104132.
[205] A. Barredo Arrieta, et al., Explainable artificial intelligence (XAI), Inf. Fusion 58 (2020) 82–115.
[206] R. Guidotti, et al., A Survey of Methods for explaining black box models, ACM Comput. Surv. 51 (5) (2019) 1–42.
[207] A. Thampi, Interpretable AI, Manning Publications, New York, 2022.
[208] European Commission, Open innovation, open science, open to the world. 2016, Publications Office of the European Union: Luxembourg.
[209] J. Lacey, R. Coates, M. Herington, Open science for responsible innovation, J. Responsible Innov. 7 (3) (2020) 427–449.
[210] R. Vicente-Saez, R. Gustafsson, L. Van Den Brande, The dawn of an open exploration era, Technol. Forecast. Soc. Change 156 (2020) 120037.
[211] T.A. Suhada, et al., Motivating individuals to contribute to firms' non-pecuniary open innovation goals, Technovation 102 (2021) 102233.
[212] H. Chesbrough, M. Bogers, Explicating open innovation, New Frontiers in Open Innovation (2014) 3–28.
[213] Y.-C. Chang, I. Miles, S.-C. Hung, Introduction to special issue: Managing technology-service convergence in Service Economy 3.0, Technovation 34 (9) (2014) 499–504.
[214] Hale, C. The MELLODDY project. 2019 23 April 2021]; Available from: https://www.fiercebiotech.com/special-report/melloddy-project.

[215] G. Barrett, L. Dooley, J. Bogue, Open innovation within high-tech SMEs: a study of the entrepreneurial founder's influence on open innovation practices, Technovation 103 (2021) 102232–102247.
[216] S. Hutton, R. Demir, S. Eldridge, How does open innovation contribute to the firm's dynamic capabilities? Technovation 106 (2021) 102288.
[217] National Science Foundation. Organizing Crowd Audits to Detect Bias in Machine Learning. 2021 24 July 2021]; Available from: https://nsf.gov/awardsearch/showAward?AWD_ID=2040942&HistoricalAwards=false.
[218] A. Lisin, et al., Digital trading applications and bank performance: evidence from Russia, J. Open Innov. 7 (3) (2021) 194–209.
[219] C. Nunes, Social responsibility and ethical decisions-a presentation of elements contained in ISO 26000, Quality 18 (158) (2017) 42–44.
[220] International Organization for Standardization. ISO 26000:2010 Guidance on social responsibility. 2010 4 Sep 2021]; Available from: https://www.iso.org/standard/42546.html.
[221] W. Zhao, Artificial Intelligence and ISO 26000, in: K. Kyprianidis, E. Dahlquist (Eds.), AI and Learning Systems - Industrial Applications and Future Directions, IntechOpen, 2021, pp. 105–116. https://doi.org/10.5772/intechopen.93451.
[222] Jarvik, L., Corporate Social Responsibility and its Discontents. SSRN 2523631, 2014.
[223] B. Shneiderman, Bridging the gap between ethics and practice, ACM Trans. Interact. Intell. Syst. 10 (4) (2020) 1–31.
[224] X. Cao, et al., Adaptive governance, loose Coupling, Forward-looking Strategies and responsible innovation, IEEE Access 8 (2020) 228163–228177.
[225] A. Kaufman, The irresponsibility of American social scientists, Inquiry 3 (1–4) (1960) 102–117.
[226] K. Krkač, Corporate social irresponsibility, Soc. Responsib. J. 15 (6) (2019) 786–802.
[227] E.-M. Forsberg, et al., Implementing Responsible Research and Innovation in Research Funding and Research Conducting Organisations, in: F. Ferri, et al. (Eds.), Governance and Sustainability of Responsible Research and Innovation Processes, Springer, 2018, pp. 3–11.
[228] Blackman, R. If Your Company Uses AI, It Needs an Institutional Review Board. Technology 2021 14 April 2021]; Available from: https://hbr.org/2021/04/if-your-company-uses-ai-it-needs-an-institutional-review-board?utm_medium=email&utm_source=newsletter_monthly&utm_campaign=strategy_activesubs&utm_content=signinnudge&deliveryName=DM127580.
[229] Bresciani, S. and M.J. Eppler, Gartner's magic quadrant and hype cycle. Institute of Marketing and Communication Management (IMCA), Universita della Svizzera italiana, Faculty of Communication Sciences, Case, 2008(2).
[230] P. Krensky, et al., Magic Quadrant for Data Science and Machine-Learning Platforms, Gartner Inc, Stamford, CT, USA, 2021.
[231] K. Arthur, R. Owen, A Micro-ethnographic Study of big data-based Innovation in the financial services sector, J. Bus. Ethics 160 (2) (2019) 363–375.
[232] J. Brennen, An Industry-Led Debate: How UK Media Cover Artificial Intelligence, 2018.
[233] Columbus, L. Gartner's 2021 Magic Quadrant cites 'glut of innovation' in data science and ML. 2021 17 March 2021]; Available from: https://venturebeat.com/2021/03/14/gartners-2021-magic-quadrant-cites-glut-of-innovation-in-data-science-and-ml/.
[234] Amazon. Our Planet. 2021 4 Sep 2021]; Available from: https://www.aboutamazon.com/planet.
[235] Apple. We're carbon neutral. 2021 4 Sep 2021]; Available from: https://www.apple.com/environment/.
[236] Google. Google Cloud's approach to responsible AI. 2018 4 Sep 2021]; Available from: https://cloud.google.com/responsible-ai.
[237] Microsoft. 2021 4 Sep 2021]; Available from: https://www.microsoft.com/en-us/research/group/customer-insights-research/articles/a-responsible-approach-to-innovation/.
[238] Stewart, M. Breadth & depth. 2021 6 August 2021]; Available from: https://tech.fb.com/responsible-innovation/.
[239] J. Lee, et al., The relationship between shared mobility and regulation in South Korea, Technovation (2021) 102327.
[240] J. Musango, et al., A system dynamics approach to technology sustainability assessment, Technovation 32 (11) (2012) 639–651.
[241] E. Samara, P. Georgiadis, I. Bakouros, The impact of innovation policies on the performance of national innovation systems, Technovation 32 (11) (2012) 624–638.
[242] B. Jaworski, On managerial relevance, J. Market. 75 (4) (2011) 211–224.
[243] E. Bender, et al., On the dangers of Stochastic parrots, in: Proceedings of the 2021 ACM Conference on Fairness, Accountability, and Transparency, 2021 (Virtual Event, Canada: ACM).
[244] R. Salminen, M. Oinonen, J. Haimala, Managerial implications in solution business research–to what extent are there managerially role-relevant implications?, in: 29th Imp-Conference, 2013. Atlanta, Georgia.
[245] C. Arun, AI and the global south: Designing for other worlds, in: M. Dubber, F. Pasquale, S. Das (Eds.), The Oxford Handbook of Ethics of AI, Oxford University Press, New York, USA, 2020, pp. 588–606.