Science and Public Policy, 2025, **52**, 329–342
DOI: https://doi.org/10.1093/scipol/scae078
Advance Access Publication Date: 25 December 2024
Article

Making responsible research and innovation meaningful in citizen science

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This study aims to explore what aspects of citizen science (CS) make the involvement of researchers (implementing CS projects) meaningful in terms of Responsible Research and Innovation (RRI) principles. Using constructivist grounded theory, we analysed semi-structured interviews conducted with 20 CS projects in terms of sensemaking and sensegiving. In terms of sensemaking, researchers of CS projects tend to implicitly self-incorporate RRI principles into work and among these principles, public engagement and inclusion are key aspects motivating researchers into CS projects. In terms of sensegiving, researchers prioritize open access and science education over other RRI principles. The lack of acknowledgment of RRI's importance in the current research culture proves to be a significant barrier to implementing these principles in a sustained manner. Likewise, experiential learning was widely practised; however, CS projects encountered different concerns and dilemmas. Therefore, tailored training on RRI is necessary for researchers involved in CS projects.

Keywords: responsible research and innovation; citizen science; meaningfulness; learning outcomes; sensemaking; sensegiving.

1. Introduction

The first European Union (EU) policy discourse about Responsible Research and Innovation (RRI), in May 2011, was given by Octavi Quintana, the Director of the European Research Area. He stated that there was a need to define RRI and involve civil society in research, to start a dialogue to avoid misunderstanding and difficulties (Owen, von Schomberg, and Macnaghten 2021). RRI relies on von Schomberg's philosophical thinking describing RRI as 'a transparent, interactive process by which societal actors and innovators become mutually responsive to each other with a view on the (ethical) acceptability, sustainability and societal desirability of the innovation process and its marketable products (in order to allow a proper embedding of scientific and technological advances in our society)' (von Schomberg 2011, quoted in Owen, Macnaghten and Stilgoe 2012: 753). This need resulted from the achieved awareness of the policy limitations on several ethical issues connected to science (e.g. genetically modified organisms, information technology, and communication; Grove-White, Macnaghten, and Wynne 2000; European Commission and Schomberg, 2011) and their impacts on society (Owen, Macnaghten, and Stilgoe 2012).

The sociopolitical issues stimulated the debate about the role that researchers should undertake in RRI. The upcoming change implied that research should be conducted in a more socially responsible manner, and this should be well evidenced (Resnik and Elliott 2016). Researchers were expected to be more active agents in producing knowledge through co-creation and contributing to the democratization of science (Metz, Boaz, and Robert 2019; Ansell, Sørensen, andTorfing 2024).

A few years later, citizen science (CS) emerged in the European debate (Serrano Sanz et al. 2014) by broadening an understanding of citizens in science, so widening boundaries of science education, which is also a principle of RRI. Although RRI and CS are formally recent buzzwords (Bensaude Vincent 2014), CS has been practised for several decades but evolved only recently (Senabre Hidalgo et al. 2021) while RRI has just completed its first decade. Combining both RRI and CS challenged the usual research work of researchers not only in terms of the competencies required but also because of conventional recognition of their academic career (Schade et al. 2021). Alongside with the developments of RRI and CS, some unclarities remained how to meaningfully embed RRI principles and CS in research practice.

Although neither term needs a comprehensive conceptualization, which has been already attempted in terms of social and ethical aspects of research and innovation (R&I) (Ribeiro, Smith and Millar 2017; Smallman 2018; Thapa, Iakovleva, and Foss 2019), they need an explanation of their interlinkage and aspects of meaningfulness of researchers' (the ones who implement CS projects) efforts to integrate RRI and CS in their research. Authors of this study seek to fill the gap by finding out more about implications related to CS in conjuncture with RRI to make researchers' participation meaningful. In this regard, we aim to explore what aspects of CS make the involvement of researchers meaningful in terms of RRI principles.

In the following sections, we first explicate the interlinkage of RRI and CS and then conceptualize RRI in CS in the light of sensemaking theory. Second, we describe the methodological approach and continue with the findings. Finally, we end this paper with discussion and conclusions.

2. Togetherness of RRI and CS

RRI encompasses public engagement, gender equality, science education, ethics and open access, and targets any type of actors using participatory avenues in all stages of R&I processes and in a thorough R&I governance (Owen, von Schomberg, and Macnaghten 2021; RRI Tools, https://rri-tools.eu/). The linkage between RRI and CS was comprehensively unfolded through the policy lenses (e.g. democratization of science, participatory action research, and knowledge co-production) (Schade et al. 2021; Senabre Hidalgo et al. 2021), open science (e.g. Shelley-Egan, Gjefsen, and Nydal 2020); therefore, we further use alignments to extend the capacity of this linkage.

The linkage between RRI and CS transcends discussions about the terminology of CS (Eitzel et al. 2017), the definition of CS (Heigl et al. 2019), including the demarcation of the conceptual boundaries between crowdsourcing, community(-based) participatory research or public participation in scientific research, thus focussing on the 'public engagement' aspect of RRI (Schade et al. 2021). In addition, principles of CS [ECSA (European Citizen Science Association) 2015] or quality criteria for CS (Heigl et al. 2018; WWU Münster 2020) cover certain aspects of RRI to a certain degree, such as public engagement, ethics, open science, and in some cases, also governance. In addition, (funding) policies in the EU also focused on aligning science with the needs and values of society, such as the former Science-with-and-for-Society (SwafS) programme, which was shaped by the idea of RRI (Schade et al. 2021; Völker, Slaattelid, and Strand 2024). This was achieved with the ECSA advocacy work, which led to the participation and research being 'better conceptualised and carried out in more significant ways' (Vohland et al. 2021: 48) and RRI being 'seen as one of the preconditions for enabling social innovation in citizen science' (Butkevičienė et al. 2021: 325).

The aforementioned alliance makes RRI and CS intertwined (Schaefer et al. 2021); however, this is not the only aspect. Furthermore, some (national) CS web platforms that list CS projects or CS networks have published criteria for principles of CS. For example, the ECSA's ten principles of CS address some principles related to RRI, such as ethics, governance, public engagement, and open access and data [ECSA (European Citizen Science Association) 2015]. This is also found in, e.g. the 'Quality Criteria for Citizen Science Projects on Österreich forscht', the Austrian CS platform (Heigl et al. 2018). The quality criteria cover RRI principles, such as ethics, governance (covered by the criteria of collaboration and communication), and open science (Heigl et al. 2018; Owen, von Schomberg, and Macnaghten 2021). Some RRI principles receive more attention in CS, e.g. ethics (LERU 2016; Jobin, Scheibner, and Vayena 2020; Ozolinčiūtė et al. 2022), public engagement, and science education (Haklay et al. 2020). While public engagement is specifically strongly discussed, its implementation in Europe is not all that easy (Bauer, Bogner, and Fuchs 2016). Science education is inextricably linked to CS, since participants usually require some basic knowledge about the subject or method at hand (Strasser et al. 2019). Indeed, the RRI principle of science education is covered by various CS projects, since the participants need some degree of factual or procedural knowledge when contributing to a project. Therefore, the aspect of learning is addressed by different authors in the field of CS. They usually cover the 'substance of learning (knowledge gained, skills and capacities developed by different types of participants, reflection); the nature of learning (nature and level of collaboration and the nature of the knowledge generation process); the distribution of learning effects among researchers and citizens; and the design of learning arrangements (how and through what kind of arrangements – training events, materials, information and communication technologies, etc. – learning is intended to happen)' (Bela et al. 2016: 992–93).

It is also apparent that RRI and CS focus on the notion of responsibility of both science and researcher, which strive for more active public involvement (namely of citizens) to achieve a greater and positive societal impact. On the one hand, CS captures the responsibility in a broader sense, i.e. it also embraces the responsibility of a citizen as part of social values (e.g. through science education; Smallman 2018; Gresle et al. 2021). Meanwhile, RRI extends the understanding of responsibility by implying the sense of care (Thapa, Iakovleva, and Foss 2019). On the other hand, CS as well as science/research alike should be responsible, i.e. sustainable, ethically acceptable, and socially desirable (European Commission and Schomberg, 2011; Stahl et al. 2014).

Considering the above features, CS approaches are fully compatible with RRI principles. Nevertheless, there are a few studies that explore what aspects of CS-related activities (e.g. CS initiatives, CS projects, and citizen observatories) are meaningful while implementing RRI (e.g. O'Grady and Mangina 2022). We invoke our study with a supportive argument by Smallman (2018) and Vohland et al. (2021), who argued that CS might benefit from RRI to make citizen participation meaningful.

Having unfolded the interlinkage of RRI and CS, we further ascribe meaningfulness of researchers' participation in practising RRI and CS using the literature on the work meaningfulness. This allows us portraying all these within our conceptual framework of meaningfulness.

3. Conceptualizing meaningfulness of RRI in CS

To enhance knowledge democracy, co-production facilitates opening knowledge systems (Jasanoff 2004), in which interactions between different stakeholders is crucial. However, co-production epistemologically and philosophically is challenging due to integration of different types of knowledge (Raymond et al. 2010). It becomes more complicated for researchers seeking to implement RRI principles by involving citizens in research practices (L'Astorina and Di Fiore 2017). Due to such complexity of researchers' work, in this section, we conceptualize RRI in CS through the lens of work meaningfulness. For this purpose, we use sensemaking theory as the most relevant approach to explore meaningfulness of RRI in CS and conclude with three research questions.

RRI principles accommodate several aspects well, such as the social, environmental, economic, and ethical (Setiawan 2018), as this is expected from CS too (Nascimento et al. 2018). As an example, Cooper et al. (2007) promote environmental awareness and responsible actions through CS. As stated in their study, residential areas are often threatened by urban sprawl, and little is usually known regarding their environmental services and biodiversity. Monitoring and managing residential lands by citizens have been proved to be a way to protect these areas from disruptive interventions (Cooper et al. 2007). This includes a couple of key concepts: science takes the responsibility to demonstrate the natural value of such areas with rigorous scientific methods, and it responds to societal needs.

In the same vein, the researchers' interview-based study by Riesch, Potter, and Davies (2013) highlighted important methodological/epistemological and ethical issues in CS projects. Concerns raised regarding ethical dimensions were towards the question of data ownership while also tackling public engagement, another principle of RRI. Also, another study explored different initiatives and strategies aimed to encourage public cooperation and their ethical and social implications (Woolley et al. 2016). The government-led research projects, such as the English *Care.data* project and the US Precision Medicine Initiative, addressed health care questions by using biomedical information about their citizens. The authors raised questions concerning ethical oversight of such medical research projects, where the balance between 'the greater good' (improved medical interventions) and respecting individual rights (including ethical values, such as trust, transparency, autonomy, confidentiality, and privacy) becomes a genuine challenge.

Using an adopted scoping review, O'Grady and Mangina (2022) explored how RRI principles transcended mainstream CS. Trust is relevant to make datasets open; however, there are concerns related to 'security, GDPR [General Data Protection Regulation], privacy, and the definition of meta-data' (O'Grady and Mangina 2022: 9) as well as to research data quality (Conrad and Hilchey 2011; Balázs et al. 2021). Direct benefit as well as multistakeholder, multidisciplinary dialogues are important in public engagement; however, more meaningful engagement is missing. Orientation towards the next generation of researchers stands out as key in science education; nevertheless, the educational dimension of citizens' mission is unclear. Gender is multidimensional (e.g. assurance of gender balance in various involvements of citizens, consideration of gender differences in research methodologies), yet CS projects fail to conduct gender analysis in a more meaningful way. Ethics is scarcely addressed (e.g. ethical approval is seen as a paperwork at the beginning of a CS project; obtaining ethical approval is not explicitly mentioned). These shortcomings and uncertainties require a better understanding of meaningfulness of researchers' participation in CS activities (part of their work) when achieving RRI, namely *R&I outcomes*, namely sustainability, ethical acceptance, social desirability, and *learning outcomes* (RRI Tools, https://rri-tools.eu/; von Schomberg 2011; Smallman, Bouwers, and Miller 2016). R&I outcomes refer to short-term and long-term impacts. Short-term R&I impacts are usually achieved during a CS project while long-term R&I impacts become more evident after a 6–10 year period of a CS project end. Taking into consideration the different periods of RRI and CS entries in the research practice (Vohland et al. 2021), we focus on ongoing CS projects. This allows us exploring only short-term R&I impacts in this study.

To address short-term R&I impacts and learning outcomes from the perspective of researchers' work meaningfulness, we adapt notions from the literature on the work meaningfulness. We refer to three-dimensional meaningfulness: meaningfulness as motivation to learn (Foster 2008), meaningfulness of being responsible (Claes and Note 2016; Kimura and Kinchy 2016), and meaningfulness as 'a general desire to lead a fulfilling life' (Claes and Note 2016: 242) through the lenses of sensemaking and sensegiving and align them with R&I and learning outcomes (see Fig. 1).

Meaningfulness as motivation to learn is described as willingness to be an active participant and develop deep interests in the content (Foster 2008). In this regard, meaningfulness of learning is enhanced by good combinations of content, pedagogy, and technology (Foster 2008). Engaging ways (e.g. congruent instructions, raising ambition through thinking about big ideas in science, creating personal stories) are of high importance as they focus on the content to be learnt and make the activity worthwhile and meaningful (Foster 2008). Motivation to learn derives from the interest to diminish 'a gap between a given and desired state of knowledge' (Keller 1983, quoted in Foster 2008: 605). The interest resides at individual needs, which are implied in relevance and meaningfulness. In our conceptual framework, motivation to learn is aligned with *sustainability* as long-lasting interests in engagement.

Meaningfulness of being responsible refers to exposing values and attitudes of individuals towards ethics, achieved through 'knowledge hierarchies by institutionalizing dialogues with community organizations' (Kimura and Kinchy 2016: 343). It is also associated with a holistic model of meaningfulness, which outlines individuals' value-oriented aspirations, beyond themselves (Claes and Note 2016). Experiences are meaningful when people conduct actions that fulfil values relevant to their existence and explain why it is worth committing to engagement (May, Gilson, and Harter 2004; Allan, Autin, and Duffy 2014). In addition, they include a series of emotions that are important as well as the achievement of values or results, such as pride, inspiration, satisfaction, elevation, or self-transcendence (Haidt 2003; Carton 2017). In our conceptual framework, being responsible is associated with *ethical acceptance* as showing values and attitudes of (principal investigators/project managers) of CS projects.

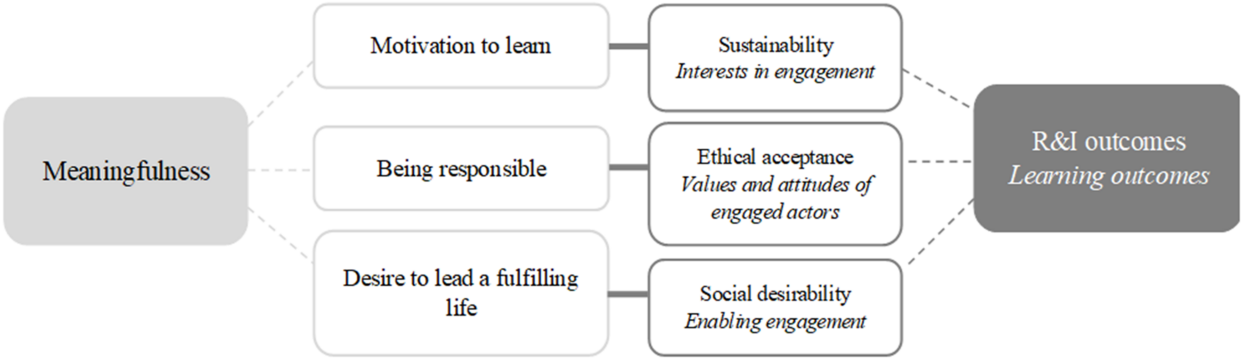

Figure 1. Framework of alignment of meaningfulness with R&I and learning outcomes

Meaningfulness as 'a desire to lead a fulfilling life' (Claes and Note 2016: 242), the so-called Wolf's model, is detached from self-interest and altruistic reasons. Here, personal aspects, such as self-actualization and personal growth or other-oriented aspects (e.g. helping others and contributing to the greater good) are not considered as part of a fulfilling life. The understanding of such meaningfulness allows rather unravelling an engagement-driven fulfilment. In our conceptual framework, a desire to lead a fulfilling life relates to *social desirability* of enabling engagement.

In this study, we focus on paramount constituents of sensemaking theory, namely sensemaking and sensegiving, to further explore what R&I and learning outcomes RRI produces in CS projects. *Sensemaking* helps to comprehend rationalized images of what individuals do (Weick, Sutcliffe and Obstfeld 2005). In the context of CS, sensemaking refers to experience-based actions, including attitudes towards RRI that guide these actions, in a CS project. Sensemaking would also refer to what a CS project ought to do because of requirements for research conduct and project implementation. Meanwhile, *sensegiving* testifies endeavours to influence the understanding of others of what should be meaningful for them (Gioia and Chittipeddi 1991). In the context of CS, sensegiving refers to affecting the understanding of the ones that belong to the CS project team as well as the ones who are involved in the CS project (citizens and other stakeholders). Such endeavours are needed to researchers to enable the meaningfulness of their efforts to integrate RRI and CS in their research practice.

To find out R&I outcomes (short-term R&I impacts), such as sustainability, ethical acceptance, social desirability, and learning outcomes, through the perspectives of sensemaking and sensegiving, we formulated three research questions: How does RRI contribute to the meaningfulness of CS projects and in which CS aspects? What motivates researchers to accommodate RRI principles in CS projects? What impedes researchers in accommodating RRI principles in CS projects? These three research questions help to identify the meaningfulness of CS projects to apply RRI principles in practice.

4. Methodological approach

4.1 Sampling

To set up an initial pool of potential CS projects, we applied a purposive criterion-based sample. We foremost defined inclusion criteria, such as (i) European researchers (principal investigators/project managers) that are running (at least) one CS project; (ii) researchers who may represent different organizational settings with scientific orientation (e.g. academia, museums, and others) within Europe; (iii) the CS project, started before 2013 (year of introducing the concept of RRI into EU R&I policy) should be ongoing during the research conduct, or the CS project started in the period of 2014–18 (the year 2014 was a starting point since it is the date of embedding RRI in the EU R&I policy as a mandatory component of all research activities) should be still ongoing; and (iv) the CS project covers any academic discipline. We listed platforms of multiple CS projects, no longer existing CS project's website (e.g. no possibility to reach a potential informant) and no clear contact details on the CS project's website (e.g. e-mail) among exclusion criteria. As an initial step to make such a list, we revised the list of CS projects publicized in Wikipedia ($N = 354$ (https://en.wikipedia.org/wiki/List_of_citizen_science_projects accessed on 19 July 2021.)). This list was later filtered according to our inclusion criteria. To enrich the list of potential informants, we continued to fill it in by adding CS projects from authors' home countries.

Our refined pool consisted of 148 CS projects, but overall, following repetitively the inclusion and exclusion criteria, we identified 117 CS projects relevant to our study's aim (Table 1). Nevertheless, we could not reach a high interest in our study through personalized e-invitations. Therefore, we posted our invitation to participate in the study in a newsletter within the citizen science community (e.g. ECSA) and in social media targeting specific groups and using hashtags, namely on Facebook and Twitter. We reused social media as a communication channel once 2 weeks after the first post. Given our diverse recruitment strategy, we found the use of social media inefficient to increase the interest in our study (only one CS project and a platform of multiple CS projects (the latter irrelevant one) contacted us).

Since the integration of RRI principles is expected, first, from researchers/researchers as part of their responsibilities taken over, we invited those who had experience in CS project management or coordination at some or all stages of a CS project (principal investigators/project managers). We included CS projects of any size by the number of citizens involved and any funding source to ascertain on which RRI principles CS projects focus without EU funding but find worthwhile to implicitly implement RRI principles in practice. This allowed us to broaden the understanding of

Table 1. Sampling.

Group of CS projects	Number of pre-identified CS projects (refined pool)	Number of identified CS projects (pre-final pool)	Number of self-identified CS projects
Started until 2013, but still ongoing	58	49	–
Implemented with the period of 2014–18	90	68	1

meaningfulness of researchers' participation in implementing RRI principles and CS.

We sought a purposive criterion-based sample (Patton, 2002) of at least three CS project managers/principal investigators in selected European countries; however, in most cases, it was not possible to clearly identify a specific European country due to two reasons. First, it was unclear in which country a CS project is carried out (e.g. due to the use of an app accessible to all kinds of users). Second, some CS projects are rather run at European level and therefore cover more than one country. Overall, 20 CS projects consented to take part in the study, of which seven were CS projects that started until 2013 and thirteen that started in the period of 2014–18 (five females and fifteen males). It is notable that some CS projects preferred to delegate project personnel other than principal investigators/project managers because of, e.g. their long-term involvement in and good cognisance of the CS project.

To conduct specific RRI principles targeted interviews, we pre-filled the basic information sheet of each CS project and provided them to the informants for verification. In the basic information sheets, RRI principles relevant to their ongoing CS project objectives were accurately identified. There, open access ($n = 18$), public engagement ($n = 18$), and science education ($n = 16$) are predominant. CS projects covered three RRI principles by average. In addition to these, some informants ($n = 2$) indicated that their CS projects contribute to sustainability (e.g. they feed in national reports on climate change), target vulnerable people (e.g. with disability or impairment) and focus on 'citizen science' or do-it-yourself science. CS projects covered different academic disciplines, such as psychology, zoology, biology, ecology, linguistics, palaeontology, history, and others.

4.2 Data collection

Data were collected using semi-structured interviews, mostly in 2021. We constructed a questionnaire consisting of four items: self-identity and ties with CS, enablers of RRI in CS, limitations of RRI in CS and impact of RRI on CS. Each item covers several interview questions (e.g. How were/are these RRI principles important in your project? Why? In what positive way did RRI principles affect your project? In what areas did you face obstacles when incorporating RRI principles in your project?) (Supplemental material).

We used remote interviewing for data collection thereby enabling informants to select the means of communication for remote interviewing and a mutually acceptable technological solution (e.g. Skype, Zoom, or other communication means). The interview language was English, except for one interview that was held in the participant's first language and then translated into English. Though some interviews had minor language-specific flaws (for most informants, English is not a native language), they did not interfere with understanding an informant. Each interview was audio-recorded. The length of interviews varied from 24 to 98 min (53 min on average).

Non-pseudonymized full interviews contained an average of 6,409 words. Different strategies were used to validate all interview transcripts for purposes of data accuracy and clarifying inaudible responses (e.g. validation of half of transcripts involved two researchers, then validation of eleven transcripts involved interviewees). Before this round of validation, we identified fifty-three inaudible or hardly audible incidents due to internet disruptions and speech speed. Also, informants, whose transcripts were subject to pseudonymization, were invited to contribute to the pseudonymization of transcripts and clarify hardly audible incidents as part of another round of validation. Eleven of the twelve informants contributed to this round of validation. This allowed us to minimize the risk of unintentional disclosure of places, dates and other information that identify them. Also, such involvement turned into the decrease of the number of inaudible incidents by 89 per cent. To our consideration, there was no significant loss of an informant's comments.

4.3 Research ethics

Participation in the research was voluntary. Each informant received a written informed consent form (including consent message for personal data processing) and a description of the study. Each informant granted permission to audio-record the interviews. Nine informants allowed us to publish pseudonymized transcripts while eight informants preferred to have non-pseudonymized transcripts published. Three informants disagreed to make us publish a pseudonymized transcript as open research data.

The study has been approved by the Ethics Committee of the University of Vienna (ref. 00597), the Research Ethics Commission of Kaunas University of Technology (ref. M6-2021-05), the Research Ethics and Integrity Commission of the National Research Council of Italy (ref. 0065527/2019) and the Ethics Commission of the Faculty of Sciences of the University of Novi Sad (ref. 0601-299/3). This study was conducted in compliance with the national guidelines of TENK (Finland) as well as the guidelines of Hanken School of Economics.

4.4 Data analysis

We analysed data using constructivist grounded theory, which allowed us to explore interpretive understandings of meanings in which values and facts are interrelated (Charmaz 2011; Žydžiūnaitė and Tauginienė 2017). The iterative approach of constructivist grounded theory helped to reveal multiple social realities within CS projects, e.g. enablers and limitations (impediments) of RRI in CS. Using a deductive approach constructivist grounded theory helped us also to test sensemaking theory in a different context and further develop it (Makri and Neely 2021).

We used a close coding of statements, decomposed our data into components and then qualified actions (Charmaz 2012). To progress through inquiry, we initially coded incidents that define assumptions, actions, and imperatives related to these actions, then synthesized them into larger segments, specified to get more extensive insights and then we reconsidered

Table 2. Illustration from the codebook.

Outcomes		Code	Definition of a code	Transcript
R&I outcomes	Sustainability	Addressing inclusion	Acting and being considered as well as absence of these for inclusion purposes.	We promoted an App, open to everybody. {…} So there were no gender issues, and no gender equality policy in the project because it was impossible to achieve this. (CS5)
	Ethical acceptance	Adhering to beliefs	Following personal beliefs and values towards RRI in CS projects as well as a way of thinking about the CS project's role in RRI.	<pause: 7s > . So, there is there is sort of ah … I'm going back to kind of the the personal belief that this {RRI principles} is the right thing to do and that this is to me, that's kind of the core of the motivation is a real belief in like this is the way we need to do science. (CS13)
	Social desirability	Co-creating with stakeholders	Developing collaborative actions with citizens in as many stages of a CS project as possible.	This {involving people in all kinds of project decisions} is something that we strive for. It would be super interesting also to to let people, for example, define the categories that they want to work with or let people define the topics that they want to work on. That is possible, but still the domain of project that we want to offer people is something that. (CS14)
Learning outcomes		Enhancing reuse of data	Creating conditions to further data use.	This is something that is happening so because we are part of our global method. So, already the data actually that was produced in this project, so the decomposition data, this is already something that people can see online. (CS1)

our codes (Žydžiūnaitė and Tauginienė 2017). This coding allowed us to be more precise in the way we conceptualized the categories (Aldiabat and Le Navenec 2018), notably sensemaking and sensegiving of R&I (sustainability, ethical acceptance, social desirability) and learning outcomes in CS projects (Table 2).

In the entire codebook, the number of codes varied from 8 to 36 (9 on average) per interview. There was no code that occurred in all interviews; however, some codes were used in more than half of interviews [e.g. addressing stakeholders' needs ($N = 16$), ensuring data quality ($N = 15$), addressing inclusion, maintaining relationship with stakeholders, reaching broader audience and pursuing RRI in practice ($N = 14$)]. To demonstrate the richness of the data and theoretical saturation, we shaped a conceptual framework at the beginning of our study and afterwards constantly assessed it in accordance with codes, i.e. new data did not add any further insights but rather strengthened and supported the existing codes (Aldiabat and Le Navenec 2018). Although some codes emerged in different categories (e.g. a code 'addressing inclusion' under sustainability and ethical acceptance of R&I outcomes), their interpretation is nuanced due to the definition of those categories.

Taking our conceptual framework of meaningfulness and R&I and learning outcomes into consideration, we further aligned our data with selected constituents of sensemaking theory, namely sensemaking and sensegiving (Supplemental material). To enhance the reliability of data analysis at this stage, two researchers independently assigned a specific constituent of sensemaking theory to each code. Given the interdisciplinarity of our research team, we discussed inconsistencies to reach full agreement. To note, other two unintended constituents of sensemaking theory emerged, such as sensebreaking and sensehiding (Supplemental material).

In the next section, Research findings, we provide authentic excerpts from the transcripts, as consented by informants, to demonstrate the vivid, thoughtful, and deliberate conversation. Where necessary, informants' authentic utterances were adjusted for readability (e.g. {…} marked when we omitted an excerpt to enhance coherent reading, {text} marked when we inserted a clarification to enhance coherent reading, and <text> marked nonverbal communication) and for pseudonymization purposes (e.g. [text] marked when we pseudonymized an excerpt, and <…> marked when we omitted an excerpt to pseudonymize personal, or other specific data).

5. Research findings

We provide our findings according to the three research questions. We then structured them by sensemaking and sensegiving and substantiated each of them by disclosing R&I outcomes (namely short-term R&I impacts) and learning outcomes. Such an analytical penetration to describe analysed data allowed us to answer our research questions and present aspects of CS that make the involvement of researchers meaningful in terms of RRI principles.

5.1 RRI as an element of meaningfulness in CS projects

5.1.1 Sensemaking Even if the informants were not explicitly familiar with RRI principles, they reported that they implemented them in their CS projects as part of their natural approach or inherent practice. In addition, by accommodating RRI principles in their projects, the informants engaged in reflexive practices, reflecting on their own assumptions, and values, and how these may impact the research outcomes.

> <pause: 8s> So, yes, we have developed the project in this direction, or it has evolved in that direction without us now knowing this buzzword {RRI}. So, I just think, I would say,

> we have lived certain criteria or values. (CS17) It {RRI} causes us to reflect on what we do, and it is part of the reason or the part of the structure of our innovation cycle. (CS15)

According to the informants, CS projects' success is greatly influenced by their responsiveness towards fulfilling the citizens' needs and expectations. To address stakeholders' needs, responsiveness involved modifying project design which resulted in increased participation and engagement, ultimately contributing to the project's sustainability.

> It's not fixed point' cause it … yeah, volunteers can start a project and end the project whenever they want to and and they can join anywhere in [my country]. So, it depends where they live and where they want to record. So, it's it's a lot less structured so, but we rely on having kind of thousands of recorders. (CS7)

Besides, the informants mentioned that considering the requirements of stakeholders opened up new possibilities for collaboration and co-creation, and led to the development of innovative solutions that were more likely to be embraced and put into practice.

> {..} we do not deploy services based on the most recent technology because they are only implemented on a new device or too costly device, for example. And this is a way in which the the the project has progressed, which I think has contributed to try to take into account some of these principles. (CS2)

The scientific contribution was identified by the informants as an important aspect of the CS projects especially when scientific rigour was ensured, among other measures, through data validation and project transparency.

> Uh, and uhm, it's not like social media where everybody can write because you have the responsibility of the mayor or of the municipality in the Impressum {imprint}. That's why all the answers, all the inputs that come from outside, has to be in in the redaction. (CS6)

The informants stated that their CS projects were created with the dual purpose of producing scientifically valid data while also ensuring that the data is relevant and beneficial to the public, thereby increasing the chances of its reuse by various stakeholders.

> <smiling> Uh, we want to accumu{late}, uh, we we want to make sure our data is public {…} that can use our data to make for to make a good sample size or to make baseline or or for any scientific need. (CS12)

> Uh, we we really assumed that that this was our our understanding of how citizen science should work, that that it's there … there needs to be ah a mutual relation between the researchers and the and the scientist and that just taking the data is not enough. And the least that we can do is make the data available back to everybody. (CS13)

5.1.2 Sensegiving The informants noted that RRI mainly contributes to the social desirability of CS projects as engagement-driven fulfilment. The importance of promoting public engagement is revealed by the fact that the number of CS projects has increased a lot over time, triggering this kind of involvement at larger scale, thus pursuing this RRI principle in practice. In addition, the success of CS projects is likely to be connected to an innate or unconscious inclination towards RRI principles of the project managers involved in CS projects as they work openly, share data and communicate the results, as stated by the informants.

> Uhm, I {did not have} a RRI agenda to be open. Uhm, <pause: 4s> if I go back in my research career, I started with action research actually. So, uhm, and there is a code of conduct there: you work openly, you don't hide your research. Uhm, you communicate what you're doing and why you're doing it. And I think it became part of my research philosophy, and I think therefore it overlaps with the RRI agenda to some degree. (CS20)

Social desirability of CS projects is connected to the audience involvement, such as the capacity of raising awareness on specific organisms in the environment, knowledge on own surroundings, and on environmental monitoring. Then, social desirability is also connected to the possibility to make such territorial information useful for maintaining or building relationship with stakeholders, like other networks or organizations, which can help to solve environmental problems at a wider scale, and policymakers that can take advantage of it to deal with some environmental problems.

> During the course we teach it not just how to apply the protocol out to search how to identify species, but we teach also why it is important to monitor this kind of species, why it is important to conserve the environment. (CS10)

> So, for example, bringing in the policymakers from [name of a city G] or [name of a city H] to, you know, to make them learn and consider how they can use a citizen science for air quality to address problems at home. (CS4)

Communication and sharing information also are meaningful to address stakeholders' needs, especially for those organizations that find difficult to talk to citizens, such as policymakers.

The informants recognized how CS projects increase social desirability when they reach broader audience (e.g. families, others) and knowledge spread is achieved even affecting others' work, as reported by the informants about, e.g. university students and municipalities.

> And some of them will discover pl@ntNet uh quite early in their career at the university, come back to us in their professional activities and try to design some of their professional activities based on the users or the services that they know (CS2).

> And so, it got interesting for other municipalities too and this is how we came into this direction from a private idea to something that can be used in in several

> places, and it's going to be or went to be because nowadays it it's in this way to be driven by public hands. (CS6)

CS projects also were considered meaningful regarding ethical acceptance, i.e. meaningful of being responsible through dialogue and learning, and thanks to the achievement of individuals' value-oriented aspirations, values or results. Some informants mentioned how CS projects raise public awareness by sparkling interest and providing opportunity to dig deeper into the topics, which in turn promotes responsible behaviour in the relationship with nature (e.g. avoiding touching organisms, protecting, and enhancing biodiversity).

> We try to spark the interest of players in the science behind and then provide opportunities to dig deeper into these topics. (CS9) Or we teach to don't touch the organisms when we are with them underwater. And we saw that our divers try not to touch them as much as possible depending on their diving skill. (CS10)

Other aspects connected to the ethical acceptance concern data acquired in CS projects. Ensuring data quality was usually reported by the informants in terms of the need for training citizens, providing them protocols that must be followed accurately, involving them in data quality control and giving them, as data collectors, rights to manipulate these data.

> For next year we create a tutorial or some kind of education or course for certain highly engaged volunteers. And they would then receive also certain rights, uhm, to manipulate observations on [the project] app. So, this would very much support the data quality issue. It's nearly impossible to, uh, for us to go through all all data individually or observations. And we would like volunteers to take part in this called control which requires quite some managing knowledge and experience in [field of study]. (CS8)

As CS projects can store a vast amount of data, the informants also recognized the need for reusing data by other organizations, making them publicly available.

> At the moment, it is not open access, but we also are at that level open for corporations. So, that that should be no problem. And I really want to get the data out because there's so much collected, and and should be shared. (CS18)

Among learning outcomes derived from the inclusion of RRI in CS projects, the informants mentioned the increase of project impacts and collaborations due to the visibility of the data. In addition, the more communication and feedback, the better the standardization and addressed users' needs.

Using CS tools affects others as they can use them in educational and professional activities, and participation in CS projects allows reciprocal learning and knowledge transferability, addressing stakeholders' needs, especially through an active exchange of feedback.

> Research application that that we have for for people thinking about how to address this topic and how to make people think about what we want them to do or what we are inviting them to do is something where we're addressing the RRI principles was really helpful for me because it made me spend a lot of time … on how to develop and how to implement processes that are, that are sort of open to everyone, that are not too complicated. (CS14)

> And the private collectors go in many cases out, hammer something out and send me images. And now they they start to overthink how they work on this. And they go now, many of them who work with me go outside, and write numbers on the layers and exactly know where it's out and where it's up and down and logging the localities. So, it's a learning for both of the parties. It's learning for professionals, as me, to deal with citizen scientists. It's also not always easy with many, many people thinking in different ways to work on fossils. (CS19)

In general, sustainability was less addressed but interesting comments were provided, such as regarding knowledge exploitation by addressing further communities (e.g. educators, schools) and letting other stakeholders use the data—which in turn promotes the project visibility, and the search and involvement of other institutions to continue and innovate the CS projects' experience.

5.2 Motives for inclusion of RRI in CS

5.2.1 Sensemaking The informants noted willingness to apply RRI principles, even though they have not done it yet, and others used checklists like the ten principles of CS by ECSA for guidance in the planning and implementation of their CS project including RRI.

The informants underlined that RRI and CS might be drivers for collaboration among citizens, scientists, and professionals (e.g. experts in a specific field) with different cultural backgrounds that contribute with new ideas and perspectives to respond to environmental issues and to manage processes on nature conservation also beyond the project duration. To realize the value of such collaboration, the informants shared their learning outcomes, among which is affecting others' growth over time and recognizing the effects produced due to participation in a CS project (e.g. received financial support). This shows that researchers might induce others in unforeseen ways.

> For me, I really like to see youth development. We have some young people who were in the group in April 2018, who started off kind of shy, a little bit reluctant to join in and now they are blossoming. They are talking about going on to university, and part of their university application has made reference to our citizen science group. That's great! It's encouraging for them. (CS15)

The informants explained that in the spirit of collaboration inclusion is important and included in the concept of CS. Similarly, the informants stated that their aspirations toward open access is their expression of being responsible for what they do in a CS project.

> Well, we want to map the world. So, we want to {…} be inclusive <smiling> for default {…}. (CS3) To me, it's impossible that somebody is not willing to share data, to put their data available to everybody else. (CS5)

According to some CS projects, good communication is strategic in informing society about project results, to keep citizens involved in the CS project. Therefore, it requires efforts and specific competences, and it is bidirectional. Citizens should receive prompt responses to their questions and be kept informed (e.g. by articles or public events). Users like educators can benefit from tools provided by the CS project. On the other hand, citizens' feedback and point of view can help to improve the CS project. Communication within the team and different actors (e.g. research, NGO, public institutions) also improves collaboration.

> Uh, yes definitely. So, they did, I mean, they sometimes pose questions that you would not think about. And they indeed … it would not have been without the citizens that we would have learnt about their motivations, and so they were very, very essential for that. (CS1)

The informants also noted that the combination of different experiences and background ensures knowledge transfer, and this change increases awareness of environmental issues and promotes responsible behaviour. Identifying roles and assigning responsibilities enhance the involvement of the citizens and the team. Awards and acknowledgements for citizens, and proper career improvements for researchers, are achievements that encourage active participation in CS.

> So, I profit from it academically and I also, I could use this platform and the data and the experience it gives me as a source for, for many, for many things that I've done like presentations, papers, workshops for this. This has been quite, quite a successful project, I would say, academically speaking … (CS14)

Technology plays an important role in CS projects. For example, the availability of apps for data collection, even web tools for creating a CS project, helps to increase the number of citizens, the geographical coverage and the data quality.

> {…} the participants send us always a photo when they monitored or looked something up and so it's, uhm, I say only 2% are wrong. And from this point of view, I think the data is very good. (CS16)

The informants also pointed out the importance of communicating project results as an opportunity to leave a mark of their work that could be further used by society. This is their standpoint of being responsible for what they do now, why they do it and for what it should serve.

5.2.2 Sensegiving The informants noted that their engagement and interest in carrying out a CS project relate to the goal of broader reach to different citizens. Their multi-purpose motivation derives from the interest to apply a citizen-friendly, considerate, and fun approach, as well as to follow an approach of good science (good research practice). The latter is expected from both the CS project and citizens involved, e.g. while ensuring data quality, encouraging data reuse as part of open access.

> {..} they {citizens} have to think in hypernyms. Otherwise, the theme lists won't work, and this is an improvement for tagging quality. Uhm, and this is something they they learn, and I think they they also learn that it's, uh, and, uh, very responsible work that they are doing. It's not something that's just for fun, uh, because others look at it and it has to be done in in a good way that there's no, uhm, there are no obstacles from from from the public and the visitors. (CS6)

The informants explained that open access plays an important role in giving sense to their willingness to conduct a CS project. They stated that data reuse by other stakeholders or in other formats (e.g. publications) strengthens their motivation because they observed how societal impact could be/is produced (so ensuring knowledge transferability in practice too), citizens gain new knowledge from a CS project, develop open mindedness, exchange their knowledge with CS projects, and contribute to the advancement of a field of research.

> And there were treasures hidden in these collections. And I have to say what I've done. I give them the idea that they have something really special and important things what could be important really for open public and society, not only for them, themselves. And many of them have then agreed and learnt that it's not only important to have fun, have a fossil and say, "Oh, only I know it in my, in my private office and now nobody knows it but me". Many of them then agreed with me that when it's really important, important for, or new for science or scientific areas, they open your minds. (CS19)

> So, the knowledge gained there is contributing to the forensic analysis of extreme weather events or, for instance, thunderstorms. (CS11)

The informants admitted that sometimes the way they conducted a CS project in terms of RRI principles (e.g. applying gender dimension) affected their personal development and others. This aspect shows the relevance of being acknowledged due to engagement-driven fulfilment.

> Uh, I think for some of the project, the partner group there is one person who was our gender manager actually. And [s/he] has now been moving on to a department lead position. And for sure, [her/his] experience in in gender issues is something that has made [her/him] a better boss. (CS1)

In addition, the informants mentioned another motivating factor, namely available and better resources from their institutions to conduct a CS project.

The sensegiving of the informants to continue with RRI is enhanced through realization of what a CS project made them learn. The informants identified such learning experiences as, e.g. addressing needs of stakeholders and building a relationship with them (including learning from each other), raising the public's awareness of the field, affecting others (e.g. people's well-being and health, serving as a source of inspiration for ideas development, or furthering the use of a method). To address RRI in a CS project, the informants mentioned that application of RRI principles allowed them to improve their communication capabilities and to balance their needs and their responsibility towards citizens as the society. Hence, to make RRI principles applicable to a CS project, the informants had to explore the flexibility of RRI principles.

> {From my experience in a CS project I learnt} How to apply RRI, how to appreciate RRI as a multi-dimensional construct, how to adapt RRI to different projects and to appreciate how flexible and adaptable it is. (CS15)

5.3 Impediments of inclusion of RRI in CS

5.3.1 Sensemaking In terms of sensemaking, the consideration of societal needs in general, and citizens' needs in particular are a factor impeding researchers in accommodating RRI principles in CS projects. Although researchers can gain new perspectives, insights and input from participants, they have difficulties in assessing the project's impact and making sure that the CS project meets (ethical) considerations (e.g. accountability, oversight) already from the beginning. Another obstacle for implementing RRI in CS are the structures of the research institutions themselves, such as ethics procedures, which do not take account of the needs of CS projects and are not adapted to consider citizens as active participants (and not only as research participants). The informants stated that they have to act ethically because otherwise they lose the trust of their citizens. This also means that CS should adhere to certain principles, and amongst these can be the RRI principles, but there is no consensus yet. Hence, ethical acceptance is a major issue among the informants.

Science education can also be an obstacle in pursuing RRI in practice. Training activities for citizens require adaptations from the researcher's side. These adaptations are, among other things, to adjust the language they use and define key terms as well as protocols they would normally use.

Building and maintaining relationships with stakeholders can be another obstacle. Although engaging in discussions with non-academics can be an enriching experience, it is time demanding. Then, communication is crucial throughout the entire project. Citizens require feedback and responses, e.g. regarding the data they have submitted or the CS project results. If citizens cannot engage in bilateral communication or do not receive the requested information, they become frustrated and drop out. Reaching a broader audience can also be an obstacle: if researchers do not target certain groups, they will lose citizens and thus the related multiplier effect.

The informants spotlighted the aspect of inclusion as an impediment to the implementation of RRI. Not only does the RRI principle of gender equality play a role, but so does equity in general, such as the inclusion of a wide range of citizens (e.g. people with disabilities, minors). However, inclusion requires adaptations of the CS project design. Otherwise, there are inequities in CS projects, e.g. regarding gender, background, or religion, which can impede the success of a CS project.

Open access can be an obstacle if personal or sensitive information needs to be collected in a CS project. In addition, the ownership of 'works' created by citizens and the anonymity of citizens, especially if they are minors, are issues in CS projects. Moreover, researchers are sometimes not aware how to anonymize data correctly to make them reusable. Although the CS project can create a large amount of data, their quality also needs to be ensured. Therefore, assuring data quality and standardizing data collection and protocols should already be considered from the very start. Likewise, any misuse of data should be anticipated.

Public engagement is considered a challenge itself, as it slows down the research process and increases paperwork. The more engagement is desired, the harder to implement (with the available resources, including time and personnel).

There are no clear principles that should be followed when engaging society and therefore the informants have the feeling that they are acting in the grey zones of the permissible. Moreover, CS is often characterized by trial and error, especially if project managers cannot rely on advice given by others or are guided by professionals. Working with citizens requires patience and flexibility from the researchers, including the efforts to deal with data quality at different stages of a CS project. In some cases, researchers also have a mediating role between stakeholders.

> {..} the moderator role between the students, the teachers and the scientists {were} much more important because we had a coaching function for the scientists. And {I} tried to include perspectives from the laypersons, in this case the the students and and the teachers, in the project design and then the the decisions made for the next steps. So, uhm, and I think this was quite important for this project being successful. (CS20)

5.3.2 Sensegiving Considering sensegiving, there are several factors that impede researchers in using RRI principles in the implementation of CS projects. The informants noted that pursuing RRI in practice is not easy, because of the existing research culture that does not acknowledge value of RRI. As discussed earlier in the theoretical part, RRI is rather a novel concept and many researchers, especially those who have been working in academia for many years, are not always aware of RRI principles, and do not see the need to incorporate RRI into their research, also including CS projects. The culture of resistance to RRI might be changed, but that takes time and effort.

> Occasionally, we have people, more among our elderly members who didn't grow up with the culture of RRI ideas, and so we need to explain to them about the benefits of RRI for conceptual coherence, operational credibility, and group acceptance of our ideas. So really, having worked through the COVID resistance to RRI or the obstacles of using RRI, meeting together, data collection, data analysis now uses RRI again. And now that we're getting used to COVID and we're getting used to working around COVID to maintain RRI, so really now at the end of 2021 the resistance to RRI in our group is very minimal. (CS15)

The informants also discussed that the understanding of the concept of public engagement, as one of the RRI principles, sometimes is reduced to a simple transmission of some knowledge or information to citizens. Hence, this narrow understanding does not contribute to the desired effective, inclusive and sustainable use of RRI in the CS projects.

> And and and that's consistent across, uh, you know, activities of public engagement that they are seen as something just to tell the public and and scientists don't see that that they need to invest properly within that and … and as long as we're not investing sufficiently in that, you can get very

> far with with enough funding but but it needs the support, and you need the sustainable support. (CS4)

Speaking about RRI, ensuring knowledge transferability into practice is also important. However, sometimes both citizens and government have too high expectations from the science to provide solutions to all existing problems and, when these expectations are not met this diminishes trust in science and in impact of science.

> Maybe society has some expectations from science. Also, the governments have expectations from science. Uhm, and maybe, maybe these expectations are sometimes a little bit too … set too high. One has to really consider what science is. It's an instrument. It's valuable. It can be used to solve problems of society or problems it's facing. Uhm, but one has to be … remain sober and not expect, uhm, everything from science. (CS8)

Then, the impediments relate to technical support for open access. To properly address stakeholder needs, scientists need technological solutions and training for the citizens to have awareness and skills on how to use different technologies (e.g. apps, GPS) to make the open access concept work in practice.

> So, it's not that you just download an app, and you can take pictures of [species] or something, but you need a training that you can really do this, ah, well-founded and ecologists do this for us. So, we have [nation]-wide ah team of ecologists who are doing this training of the [enterprises] and a second round was then required that this really happens according to the standardised system that, if possible, all of them do the same. (CS17)

Finally, lack of motivation of researchers to involve citizens into research, to support RRI principles and acknowledge value of RRI is one the most important impediments for RRI sustainability in a long run.

> Uh, no, that was not very, not that was very easy because there were a lot of people {who} were very creative and are very interested to help us. Uhm, more the the difficulty is to motivate the citizen scientists to do it a long term. That's, I think, the hardest point of such a project. (CS16)

6. Discussion

Our study shows that the informants are not well-aware of the concept of RRI, although the EU policy discourse about RRI has been in place for more than a decade. Nevertheless, many informants are naturally implementing RRI principles in their CS projects.

The informants of our study define RRI as the operational concept that is foundational, sustainable, integral, non-dogmatic, flexible, and intrinsic. Its implementation in practice is linked to bringing a benefit to the world, contributing to organizational development. RRI also stands as a social position of a researcher; however, it might manifest as a generational culture barrier. Taking this perception of RRI into consideration, the informants pointed out that the sensegiving to RRI in their CS projects relies on the substance of the learning from which they (might) genuinely and meaningfully benefit. Similar findings about CS as a learning process and its benefits were observed in studies by Bela et al. (2016), Gresle et al. (2021), and Smallman (2018).

The first, and the most obvious, RRI principle in the CS projects we explored is public engagement. However, the 'current **science system and culture** in Europe is largely perceived as a **main barrier** for the continuous and effective implementation of societal engagement' [emphasis in original] (Bauer, Bogner, and Fuchs 2016: 49). Reasons for this are, among others, a lack of training and skills, which was also emphasized by the informants, who either stated that they rather implemented the CS project through mistakes, while others could rely on professional advice or guidance. Although not prevalent in our study, public engagement can also be a barrier in an academic's career, since the current system of academia does not reward public engagement activities but rather focuses on a quantity of publications in peer-reviewed journals or acquired third-party funding (Bauer, Bogner, and Fuchs 2016). This might retard the commencement of CS projects in some countries, so to restrain sensemaking in CS in a general sense. The informants also alluded to the fact that adapting a CS project to the citizens' needs may also interfere with the freedom of research and autonomy of researchers in deciding which topic they address in their research. For lowering this barrier, the changes proposed at the institutional level include funding schemes, peer review and the university system itself, which is also described in the literature (Bauer, Bogner, and Fuchs 2016). Such findings from our study and previous studies (Bauer, Bogner, and Fuchs 2016) suggest that both institutional and EU policy affecting research and researchers, including implementation of RRI principles in CS, should be coherent and wide-ranging.

Some informants managed to address both gender equality and inclusion in general; however, such practice was less addressed among all RRI principles in both this study and previous studies (O'Grady and Mangina 2022). Therefore, sensegiving to gender equality (and inclusion) should be further explored in CS. As defined by Gioia and Chittipeddi (1991) and Claes and Note (2016), sensegiving shows what gives sense to the ones who carry out an activity to realize engagement-driven fulfilment. Likewise, gender equality (and inclusion) should give sense foremost to principal investigators/project managers of CS projects, so they could take this RRI principle as part of their engagement-driven fulfilment.

While science education is considered a necessary precondition for citizens engaging in a CS project (Strasser et al. 2019), also in our study, the informants mainly consider themselves as experts that teach their citizens the knowledge they need. Although several informants consider the exchange with members of the public as enriching, in terms of sensegiving it is unclear how far they integrated the citizens' ideas or feedback into the CS project. This suggests that research policy should anticipate avenues for assessment of long-term impacts of RRI principles in CS [e.g. using Impact Assessment Framework developed by Wehn et al. (2021)].

Ethics as an RRI principle considers societal values from the very start of the project (Bauer, Bogner, and Fuchs 2016); therefore, it may influence a CS project too by, e.g. having to find solutions for (societal) problems (Bauer, Bogner, and Fuchs 2016), serving the public interest (Strasser et al. 2019). The informants pointed out that research data quality in their

CS projects allowed them to publish the research results in renowned scientific journals. Although the interpretation of data quality varies among stakeholders (Balázs et al. 2021), the fact that they were recognized by the scientific community was one of the indicators for the informants that their research was conducted in a way that upholds standards of good research practice as well as serving the public interest.

Open science as an RRI principle contributes to fulfilment of accountability and responsibility (Bauer, Bogner, and Fuchs 2016: 12). Our study shows that the informants appreciate opening of data if it is further reused by different stakeholders, e.g. to showcase the scientific contribution of CS projects, to advance scientific knowledge, or to promote public engagement in science. Their observations on open access contribute to recent studies (Kimura and Kinchy 2016; O'Grady and Mangina 2022).

Our findings suggest that the interlinkage of ethics, open access, and data quality in CS is in line with the agenda of open science, an EU policy priority, which contributes to the improvement of the quality, efficiency and responsiveness of research (UNESCO 2021).

7. Conclusions

In terms of sensemaking, driven by a desire to uphold scientific rigour, ethical conduct, objectivity, reliability, and reproducibility, researchers tend to implicitly self-incorporate RRI principles into their work even though they might not always be aware of the specific concept of RRI. In certain cases, some intertwined RRI principles (e.g. open access and ethics) were more challenging than others in CS projects; however, gender equality was seen from a broader perspective, rather as inclusion.

Our findings show that public engagement and inclusion play a key role for researchers to invest their energies in CS projects. So to speak, the quality of communication within partners and with citizens, a clear definition of roles and responsibilities, and proper acknowledgements that enhance citizens' and researchers' engagement in the CS project are rationalized as both expression of being responsible and engagement-driven fulfilment of researchers.

In terms of sensegiving, our findings show that ways of influencing others are multiple and sometimes unpredictable. Here, the value of open access (namely open data) and science education are more noticeable than other RRI principles. The close sisterhood between open data and ethics was explicit, while more effective, inclusive and sustainable engagement was more desirable. The latter relates to the need for a proper acknowledgement in the existing research culture, i.e. disregard of this impedes researchers in addressing RRI principles in their CS projects in the long run. The former points to the lack of technical support and knowledge. Researchers usually develop new skills and practice through experiential learning, used to face different concerns and dilemmas. There was also an observation that to accommodate RRI principles episodically or in a limited way might affect trust in science, particularly in its impact. Given all these, customized training on RRI principles is essential for researchers working or interested in working in CS.

As is usually the case in qualitative research, our findings cannot be generalized to all CS projects, though the population of the informants is diverse. We envisage the potential of our study to further revision of EU countries' research and other public policy (e.g. environmental, innovation) as well as institutional policy to embark RRI principles in CS in more substantial and meaningful ways. Similarly, we encourage further scholarly debate about researchers' practice of embedding RRI principles in CS and their contribution to the CS and research mission.

Acknowledgements

We thank Dr Diana Marčiulynienė, Senior Researcher at Lithuanian Research Centre for Agriculture and Forestry and Dr Johan Barstad, Senior Researcher at the University College for Green Development, Norway for the contribution to the research design.

Author contributions

All authors contributed to the conceptualization design of the study and data analysis. Loreta Tauginienė (Literature review, Methodological design, Data collection, Validation of transcripts), Eglė Butkevičienė (Literature review, Methodological design, Data collection), Luciano Massetti (Literature review, Data collection), Barbara Heinisch (Literature review, Data collection), Snežana Popov (Methodological design, Validation of transcripts), Francesca Ugolini (Methodological design, Data collection, Validation of transcripts). All authors contributed to writing and editing the manuscript, read and approved the final manuscript.

Supplementary data

Supplementary data is available at *SCIPOL* online.

Conflict of interest. The first author's affiliation has been changed due to legal requirements in Lithuania. All the authors have no relevant non-financial and financial interests to disclose.

Funding

The workshop to design this study is based upon work from COST Action CA 15212 *Citizen Science to promote creativity, scientific literacy, and innovation throughout Europe* supported by COST (European Cooperation in Science and Technology).

Data availability

Nine pseudonymized and eight non-pseudonymized transcripts are available at https://zenodo.org/records/14171849 at the Zenodo repository.

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Science and Public Policy, 2025, 52, 329–342, DOI: https://doi.org/10.1093/scipol/scae078, Article