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Co-creation in support of responsible research and innovation: an analysis of three stakeholder workshops on nanotechnology for health

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ABSTRACT

Co-creation, a form of engagement in which stakeholders jointly generate value, has increasingly received attention as a way to enhance responsible research and innovation (RRI). To explore the extent to which co-creation might support RRI, this paper analyses three co-creation workshops with different types of stakeholders in the area of nanotechnology for health. The analysis considers the potential of co-creation to enhance the legitimacy of and add value to innovation based on the four dimensions of RRI: reflexivity, inclusion, anticipation, and adaptation. The results show that it is difficult to address all the dimensions at once. A trade-off between creating legitimacy and added value can be detected: a co-creation process focusing on added value requires deliberation early in the innovation process, a certain specificity and an action-oriented perspective. This comes at the cost of the inclusion and anticipation of societal values, which are important dimensions of a legitimate innovation process.

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Co-Creation; responsible research and innovation; stakeholder engagement; nanotechnology

Introduction

The potential contribution of ‘outsider perspectives’ to the production of legitimate, responsible, and socially robust knowledge and innovation has been emphasized in science and technology studies (STS) (e.g. Jarmai and Vogel-Pöschl 2020; Jasanoff 2014; Reed et al. 2018). Co-creation, a form of collaboration in which relevant stakeholders jointly generate meaning and value, has increasingly received attention as a way to enhance the responsiveness of research and innovation. Various scholars have applied the concept of co-creation in studies on the robust and legitimate development of knowledge, research, and innovation (e.g. Engels, Wentland, and Pfofenhauer 2019; Gudowsky and Peissl 2016; Gudowsky and Sotoudeh 2017; Mauser et al. 2013; Polk 2015; Voorberg, Bekkers, and Tummers 2015). Furthermore, co-creation has been proposed as an instrument to support research and innovation policy. The European
Commission, for example, uses the concept of co-creation in their definition of public engagement in responsible research and innovation (RRI), which they define as ‘co-creating the future with citizens and civil society organizations, and bringing on board the widest possible diversity of actors that would not normally interact with each other, on matters of science and technology’ (European Commission 2016, par 1). Building further on this perspective, various calls within Horizon 2020, the European Commission’s main funding programme for European research and innovation between 2014 and 2020, have promoted co-creation by including different types of professional and societal stakeholders, such as citizens, users, academia, social partners, public authorities, businesses, creative sectors, and social entrepreneurs (Gudowsky and Sotoudeh 2017).

Despite the increase in attention, the precise role of co-creation supporting RRI is not fully understood. Since co-creation has been applied in different domains, with different aims, and with different types of publics, there is a need for more clarity regarding the possible contributions of co-creation in the context of research and innovation. This paper explores the potential role of co-creation in fostering RRI by analysing three co-creation activities with different types of stakeholders in the area of nanotechnology and health. Below, we first describe the origins of and rationale behind co-creation. Then, we discuss co-creation in the context of research and innovation. Finally, we present our research question and the research context.

**Origins of and rationales behind co-creation**

Co-creation has its origins in business and public policy contexts, but it has also been applied in other domains (Gudowsky and Sotoudeh 2017). It describes a shift in thinking from the primary enactors (producers, policymakers or innovators) as definers of value to a participative process in which customers, citizens, or other stakeholders together generate and develop meaning and value (Ind and Coates 2013). Value and meaning can be created by the interaction itself -i.e. shifting power dynamics and mutual learning processes- as well as by improving the outcomes -i.e. higher quality of(new) products, policies, or innovations- (De Jong, Neulen, and Jansma 2019; Ind and Coates 2013; Malakhatka, Sopjani, and Lundqvist 2021; Voorberg, Bekkers, and Tummers 2015). In business contexts, co-creation has been applied as a participative process where customers and users (and other stakeholders) are involved in the design and development of products and services. Co-creation is regarded as a way to create value through building a meaningful relationship with customers, as well as through the improvement of products (Ind and Coates 2013). The first notion of value creation relates to the idea that individuals are linked to companies through social interaction in terms of brand awareness, service and product experience. The value of businesses is not solely based on their economic output, i.e. products, but it is the usage of products and the interaction with the organization that matters, i.e. user experience (Vargo and Lusch 2004). Whereas traditional marketing approaches tend to focus mainly on the organization by creating narratives about the brand and addressing the value of user experience from a developer’s or designer’s point of view (Jantan et al. 2020), with co-creation the creation of value proposition is a joint effort (Vargo and Lusch 2004). It is the empowerment of customers and users in this process that matters (Malakhatka, Sopjani, and Lundqvist 2021). Consequently, through co-creation customers feel more attached to the product and the
organization, which may positively affect their relations with the organization (Vargo and Lusch 2004).

The second notion of value creation revolves around optimizing the quality of the products themselves (Ind and Coates 2013). This form of co-creation is at the front end of product development and focuses on the added value of co-creation to products (Prandelli, Verona, and Raccagni 2006). Von Hippel (2005) referred to this type of co-creation when he introduced the term ‘democratization of innovation’, explaining how co-creation with (potential) end-users of a product is based on an economic rationale and initiated by companies to produce goods more effectively and efficiently. The underlying assumption is that users bring in another type of knowledge than experts, which adds value to the product (Von Hippel 2005).

In public policy contexts, co-creation can be seen as an intensive type of citizen participation, involving active collaboration between policymakers and citizens on specific policy issues. Also in this context, different aims of co-creation have been distinguished. De Jong, Neulen, and Jansma (2019) stated that co-creation can lead to (1) better policy decisions based on richer input and (2) public support for government policy through active participation. Voorberg, Bekkers, and Tummers (2015) distinguished different roles of citizens in the policymaking process: citizens as initiators, co-designers, and co-implementers. In the first type of co-creation, citizens identify problems in need of government measures; in the second type, citizens are asked to generate or prioritize ideas or solutions; and in the third type, citizens decide on or shape the execution of government policy (Voorberg, Bekkers, and Tummers 2015). In theory, the two aims of co-creation can be compatible in the policy context, but in practice, policymakers often focus on the second aim and set up co-creation activities to create acceptance and legitimacy for their policies (Silverman et al. 2019). Especially in the context of grand societal challenges, such as climate change and healthy ageing, scholars have advocated for empowering citizens in policy making processes and not just focusing on legitimacy through public engagement (e.g. Roberts 2004). Similarly, in the context of science and technology development, scholars advocated for more substantial engagement (Jasanoff 2014; Rip 2014; Wynne 2006) and more proactive approaches to democratize technologies (Ienca 2019).

Co-creation in support of responsible research and innovation

In the context of science and technology, co-creation has been used for a legitimate innovation trajectory and for robust knowledge and innovation (e.g. Engels, Wentland, and Pfofenhauer 2019; Gudowsky and Peissl 2016; Polk 2015). In this context, Voorberg, Bekkers, and Tummers defined co-creation as ‘the creation of long-lasting outcomes that aim to address societal needs by fundamentally changing the relationships, positions and rules between the involved stakeholders, through an open process of participation, exchange and collaboration with relevant stakeholders, including end-users’ (2015, 1334). This definition of co-creation closely relates to Von Schomberg’s definition of RRI: ‘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’ (2012, 9). In both definitions, the emphasis lies on interactions between different types of
actors or stakeholders and the changing responsibilities and relationships between these stakeholders in the innovation process, from a top-down process to mutual responsibility. Furthermore, both Voorberg, Bekkers, and Tummers (2015) and Von Schomberg (2012) focus on legitimacy and on the value of innovation.

To gain a better understanding of how to bring RRI in practice, Stilgoe, Owen, and Macnaghten (2013) developed a framework based on four integrated dimensions: reflexivity, inclusion, anticipation, and responsiveness. Reflexivity asks from scientists and innovators to look beyond their key responsibility for innovation development by opening up their innovation trajectory and reflecting upon their moral and societal responsibilities (Stilgoe, Owen, and Macnaghten 2013). Inclusion concerns the engagement of stakeholders, including citizens, in the innovation trajectory, which enhances the legitimacy of the innovation (Stilgoe, Owen, and Macnaghten 2013). Anticipation involves considering the potential impacts of innovation and discussing possible desirable futures with societal actors, which can be achieved through public engagement activities (Stilgoe, Owen, and Macnaghten 2013). Responsiveness includes ‘responding’ to societal needs and values and ‘reacting’ in adjusting the innovation based on these and values (Stilgoe, Owen, and Macnaghten 2013). Foley, Bernstein, and Wiek (2016) called this last dimension ‘adaptation’, arguing that adaptation implies intentionality among stakeholders and a course of action based on experimentation, while responsiveness may be limited to a rather haphazard response of stakeholders to societal needs and values (Foley, Bernstein, and Wiek 2016). According to Stilgoe, Owen, and Macnaghten (2013), the four dimensions together lead to a legitimate innovation process and more robust innovations.

Co-creation seems to reflect these two aims of RRI and has been regarded by the European Commission as an instrument for democratizing science and technology (European Commission 2016). Various research projects within the European Horizon 2020 framework have aimed for a better understanding of co-creation and its outcomes for RRI. However, these projects mainly focused on presenting the benefits of co-creation for a legitimate innovation process, and the power of co-creation to generate innovative solutions and the circumstances for creating these outcomes have been widely overlooked (Robinson, Simone, and Mazzonetto 2020).

**Research question and context**

In this research, we draw from the insights of studies on co-creation and those of RRI to create a better understanding of how co-creation can be implemented in innovation processes. We studied the following research question: How can co-creation with stakeholders support RRI practices by aiming for a legitimate innovation trajectory and/or added value of the innovation? Stilgoe, Owen, and Macnaghten (2013) four dimensions – reflexivity, inclusion, anticipation, and responsiveness – were used to specify ‘responsible’ in RRI in practice. Following Foley, Bernstein, and Wiek (2016), we replaced responsiveness with adaptation, which suggests a more conscious process of adapting innovations based on co-creation outcomes and as such better reflects the aim of adding value to innovations.

The present study was conducted as part of the European Horizon2020 project GoNano. The GoNano-project is based on the belief that research and innovation can
benefit from being more open to societal needs and concerns through co-creation with relevant stakeholders along the value chain. The aim was to explore how different types of stakeholders can contribute to the development of future nanotechnologies in the areas of health, food, and energy, by means of a citizen consultation and co-creation workshops in three pilot countries. The current research is based on the outcomes of the Netherlands, the pilot country that focused on health.

Nanotechnology is considered a promising technology for health applications. It can offer solutions for therapeutic interventions, new ways of monitoring health and diagnosing diseases, and personalized and targeted medicines (Contera et al. 2020; Metselaar and Lammers 2020). Although many products already contain nanoparticles, most innovations that might radically change society, including nanomedicines are still in their developmental stage (Contera et al. 2020; Metselaar and Lammers 2020). These innovations are often out of sight for the people who will be affected by them because they are being developed in laboratories and other secluded arenas (Foley, Wiek, and Kay 2017). However, there are fears that as soon as the technologies will be implemented and commercialized, they are met with public resistance. Concerns about nanotoxicity and environmental impact, regulatory hurdles and uncertainty, and concerns about falling public confidence have fostered the endeavours of developing nanotechnologies in a responsible way (Russel 2013). In fact, nanotechnology is considered the leading field for activities and discussions about RRI (Rip 2014). In their analysis and reflection of RRI initiatives on nanotechnology, Shelley-Egan, Bowman, and Robinson (2018) found that research into what should constitute RRI has received substantial attention, but the actual uptake of RRI by relevant actors and the actual effects of RRI on practices of researchers and innovation actors remain unclear. In this research, we address this by analysing how co-creation can support RRI and can lead to legitimacy and more robust innovations.

**Method**

**Design**

To answer our research question, we compared and analysed three co-creation workshops on nanotechnologies for health, which were organized in the Netherlands. Various representatives of stakeholder groups participated in those workshops. Each workshop lasted approximately 4.5 h and followed the same methodology based on the general principle of design thinking (Yoo et al. 2013).

The workshops were preceded by an interview study with experts ($N = 5$) to identify promising nanotechnologies for health and a face-to-face consultation with citizens ($N = 50$) to collect their societal needs and values regarding those technologies. Based on the interviews, promising applications were explored, which included monitoring and diagnostic devices for diabetes patients, sensor technologies for better detection of cancer, and improvements to policymaking for nanotechnologies. These applications were first presented to the citizens in a citizen consultation through future scenarios, which were written down in short stories. The citizens discussed these scenarios in smaller groups and based on these discussions various values were deduced. These include well-being, autonomy, privacy and security of health data, affordability of healthcare,
accessibility of healthcare, safety, and health. Furthermore, citizens formulated specific needs when developing nanotechnologies for health, that is, to focus on prevention of diseases, to limit continuous awareness of health data, to safeguard ownership of data, to include the health professional in the care loop, to focus on the usability and potential implications of nanotechnologies and to educate and inform citizens about health technologies (Jansma, Dijkstra, and De Jong, forthcoming). The outcomes of the citizen consultation were used to anticipate potential impacts and desirable futures in the co-creation workshops reported on in this paper.

**Participants**

An important factor for setting up a co-creation process is to identify and select the stakeholders to engage with. First, a categorization was made of relevant stakeholder groups involved in the development of science and technology, which included citizens, researchers from academia, policymakers, businesses, and CSOs. At the three workshops, a mixture of stakeholders from these groups were selected. Second, we identified key stakeholders who had interests in the topics of the co-creation workshops. Based on interviews with those key stakeholders, other relevant stakeholders were invited and 40 personalized invitations were sent out, aiming at approximately ten participants per workshop with a variety of backgrounds. There were many positive responses, as 31 stakeholders initially agreed to participate, five of whom had to cancel last-minute due to unforeseen circumstances. In total, 26 stakeholders participated (see Table 1).

A key stakeholder in the workshop on diabetes technology was the Dutch Diabetes Foundation, which represents the interests of diabetes patients in the Netherlands and invests in promising technologies for treating and curing diabetes type 1 and 2. Based on an interview with a representative of this organization, a representative of a business working on an artificial pancreas for treating diabetes type 1, a representative of a business working on detecting diabetes type 2 at an early stage, and a representative of an organization working on the development of a regenerative therapy for diabetes type 1 were invited. All three technologies are based on nanotechnology. The representative of the Dutch Diabetes Foundation, the CEO and business developer of the company working on the artificial pancreas and the CEO of the company working on the early diagnostic device were present at the workshop, but no representative of the organization working on the regenerative medicine could come. Additionally, three researchers working on nanotechnology for diabetes applications, a senior policymaker

| Table 1. Stakeholders present at the three co-creation workshops. |
|---------------------------------------------------------------|
| Product development for diabetes (N) | Research on sensors for cancer detection (N) | Policymaking for nanotechnology in health (N) |
| Citizen (patient) | 1 | 0 | 2 |
| Researcher from academia | 3 | 5 | 2 |
| Business representative | 3 | 2 | 1 |
| Policymaker | 1 | 0 | 4 |
| CSO | 1 | 1 | 0 |
| Total | 9 | 8 | 9 |
involved in advising the national government for diabetes policies, and a diabetes type 1 patient – who also attended the citizen consultation – were present.

A key stakeholder for the workshop on sensor technologies was a professor of advanced materials at a nanotechnology institute working on improving the diagnostics and treatment of diseases through (bio)-medical nanotechnology applications and who is the representative for health technologies at the sensing programme of this institute. Based on interviews with this professor, a post-doctoral researcher who works on the development of sensors for better detection of cancer through proteins and two researchers from other disciplines (biomedicine and oncology) were invited, as well as a representative of a company working on the detection of cancer through urine. The four researchers from various disciplines and two people from the R&D department of the company were present. Additionally, a social science researcher and a representative of a CSO focusing on responsible innovation and technology assessment were present.

A key stakeholder for the workshop on policymaking was the director of a research institute on nanotechnology. Based on the interview with this stakeholder, a representative of a funding organization, a representative of a business valorization organization, and a senior policy maker of the Ministry of Health were invited. The director, two programme leaders of a funding organization and a representative of the business valorization organization were present. The senior policymaker had to cancel at the last minute. Additionally, the national risk coordinator of nanotechnology, one nanomaterials scientist, one social scientist, and two citizens who also participated in the citizen consultation were present.

**Specific application areas**

Based on the interviews with key stakeholders and the participants who agreed to come to the workshops, application areas and aims for the workshops were identified. One workshop addressed monitoring and diagnostic devices for diabetes patients, focusing on improving product development. The second workshop was about sensor technologies for better detection of cancer, focusing on improving and adjusting the research. The third workshop was about policymaking for nanotechnology and health, focusing on creating a framework for policymaking. The first two workshops were relatively specific: the first workshop was application oriented, addressing a technology in its late developmental stage, and the second workshop was technology oriented, addressing a technology in an early developmental stage. The third workshop was policy oriented and addressed a particular nanotechnology application for health.

**Procedure**

The procedure of the co-creation workshops was based on four distinguished phases of design thinking: exploration, ideation, prototyping, and reflection. These phases foster creativity and promote the integration of different types of knowledge (Yoo et al. 2013).

In the exploration phase, participants introduced themselves, and the specific topic of the co-creation workshop was presented. In the co-creation workshop on diabetes, two representatives from different technological start-ups presented their products. One product was an artificial pancreas, which is a device for diabetes type 1 patients that continuously monitors the blood and automatically injects insulin when needed. The other
product was an early diagnostic device that can detect diabetes type 2 at an early stage before any symptoms occur. In the co-creation workshop on sensor technologies, a scientist presented her research on sensors for better detection of cancer through proteins. In the policy-related co-creation workshop, there was no focus on a specific technology or research. Instead, the moderator introduced the question to the participants about how to increase RRI by integrating societal needs and values in product- and research development in nanotechnologies for health.

During the ideation phase, the participants responded to the presentations based on insights from their (personal or professional) background. Then, the moderator introduced the values and needs from the citizen consultation. The participants deliberated in subgroups on how the product suggestions, research line, or policy framework could take into account these values and needs, coming up with ideas for improvement.

In the prototyping phase, the participants selected one of the ideas and created a storyboard. In the storyboard, various stakeholder perspectives, such as the perspective of the patients, policymakers, scientists, developers, and health professionals, were included. By making such a storyboard, the participants developed their ideas into specific suggestions and included various types of knowledge.

The co-creation workshop ended with the reflection phase, during which the two subgroups presented their ideas to each other. The subgroups were asked to come up together with a plan for follow-up actions based on the presented ideas.

**Analysis**

The co-creation workshops were analysed based on the collected materials, existing of the observations and the recordings of the workshops, the questionnaires that were distributed at the end of each workshop, and the interviews that were conducted after all three workshops. The first two authors of this article organized all co-creation workshops and were present during the workshops. They recorded the workshops and made extensive notes, which provided insights about the dynamics during the workshop. Furthermore, at the end of each co-creation workshop, an evaluation questionnaire was distributed that included questions regarding the outcomes of the co-creation workshops and the process itself. These provided insights into the participants’ perceptions of the workshops. Additionally, after organizing the three co-creation workshops, evaluation interviews were conducted with stakeholders who participated in one of the co-creation workshops. These interviews were held with a business representative, a researcher, and a CSO representative who participated in the diabetes workshop, a researcher who participated in the sensor workshop, and a policymaker and citizen who participated in the policymaking workshop. The semi-structured interviews included questions about the co-creation process and the outcomes of the workshops and lasted between 30 and 40 min and added more insights into the effectiveness of the co-creation process.

**Results**

First, we describe the dynamics and outcomes of the three co-creation workshops. After that, we reflect upon the four dimensions of RRI, i.e. reflexivity, inclusion, anticipation, and adaptation, in relation to the three co-creation workshops.
Dynamics in the three co-creation workshops

Product development for diabetes patients

In the co-creation workshop on diabetes, suggestions were made for two products. For the artificial pancreas, the participants came up with a data management plan for the use and sharing of data collected with this device. Stakeholders suggested changing the functionality of the artificial pancreas in a way that the user (patient) would get more autonomy by giving him or her the opportunity to decide what would happen with the collected data. They suggested four options for data sharing. One option was to not share any data at all and to keep the analysis of data restricted to the patient. In this way, privacy and security of the data would be safeguarded. Another option was that the data would be directly sent to a health professional, who could inform the patient when an anomaly would be detected. In this way, the patient would not be continuously reminded to his or her health data – improving a patient’s well-being – and the healthcare professional would be included in the care loop. Another option was to share the data with a caregiver who could monitor the patient’s health data. This could be especially useful in the case of patients who are less able to interpret data themselves and would increase the accessibility of the device. In the fourth option, the data would be sent to the company developing the device, which could improve the device based on big data analysis.

The data management plan represents a number of values and needs that were defined earlier by the citizens. The various stakeholders were all able to contribute to the suggestions for the data management plan, and the results of the questionnaire indicated that the stakeholders were positive about the process of the workshop. Furthermore, the outcome was regarded by the stakeholders as relevant and feasible. However, in the evaluation interview, the business developer of the company working on the artificial pancreas stated that he would not (yet) implement the suggestion in their product. Although he acknowledged the relevance of data management and learned from the workshop that it would be good to integrate a functionality to personalize the data sharing, the company had other priorities.

The subgroup that worked on the early diagnostic device for detecting diabetes type 2 suggested an implementation plan. The stakeholders came up with indicators for implementation. These indicators include defining the target audience of the device, either all people or only high-risk people; deciding upon the place where the device can be implemented, e.g. in a general practitioner’s (GP) office, communal centre or other public places; thinking about the person who operates the device, e.g. a doctor, nurse or volunteer; deciding upon how to motivate people to use the device, e.g. a national campaign, information distributed at GP’s office, through other health professionals or through peers; and thinking about who should initiate the campaigns and pay for the use of the device, e.g. the local health authority, national government, an insurance company or citizen themselves.

The stakeholders did not focus on the design and technicalities of the device but on the implementation and use. The different options in the implementation plan reflected various needs and values of the citizens, including affordability and accessibility of healthcare, the need for preventive healthcare, inclusion of the health professional in the care loop and creating awareness of health technologies, and were formulated
based on the different perspectives of the stakeholders. For example, the policymaker explained how the organization of a national campaign works and the CSO representative explained how awareness among citizens for diabetes (type 1 and 2) could be created. The CEO of the company that develops the device emphasized that he gained insights into the social context where his product would be implemented, which he had not considered before. However, he was not planning any specific follow-up action based on this suggestion because the product was still in an early developmental stage.

**Research development for sensor technology**

In the co-creation workshop on sensor technologies, suggestions were made for the development and improvement of a research project on the detection of cancer through proteins. Participants were divided into two subgroups, and both groups had difficulties using the output of the citizen consultation as a starting point. Instead, they addressed several other issues and suggestions based on their professional background and expertise. One group mainly focused on the application of the research and emphasized that the research would be improved by identifying for which types of cancer there is a need for better diagnosis and by talking to healthcare professionals and medical researchers. The other group addressed how the technology itself could be improved by suggesting improving the device by labelling cell-specific proteins through desk research, interviews with other researchers in this field, and empirical research. For the latter step, a plan was made of how to obtain tumour cells for the study and how to obtain access to laboratory equipment.

In this workshop, the stakeholders discussed more technical details of the research and the potential application. By including researchers with different backgrounds and societal actors, specific suggestions for improving the research trajectory and thereby the development of the technology were being made. However, the participants did not connect their suggestions to the outcomes of the citizen consultation since these outcomes were not technology oriented. Furthermore, not every participant felt he or she could contribute, as the workshop required specific (technical) knowledge. Although most participants thought the workshop was interesting and led to relevant insights, they did not perceive an added value for their own area of expertise. Only the researcher whose research was discussed thought the workshop added great value.

**Policymaking for nanotechnology and health**

In the co-creation workshop on policymaking, stakeholders were asked to suggest ideas to stimulate RRI in policymaking on nanotechnologies for health. Two subgroups were formed to develop a particular idea. One idea involved mission-oriented research and innovation based on specific solutions for a societal problem. The other idea was a field lab where researchers can test their technologies with (potential) users. The mission-oriented research was based on the insight that societal challenges could not be approached by one innovation, but a combination of multiple innovations would be needed. Instead of concentrating on one specific innovation or type of research, the participants suggested defining a clear mission. This would include a restructuring of funding schemes and research groups. The stakeholders did not base this idea on the outcomes of the citizen consultation but emphasized that societal needs and values should be taken into account when defining the mission. Although the stakeholders thought that
the idea of mission-oriented research was relevant, they expressed concerns about the feasibility as it required a systematic change in research and innovation and involvement of a wide variety of stakeholders. Furthermore, the participants of the workshop thought the idea was rather abstract without a plan for follow-up actions.

The idea of the field lab was derived from the stakeholders’ observation that many health technologies take a long time to reach the market and that there is a gap between the technologies being developed in laboratories and wishes and needs in society. In the suggested field lab, novel nanotechnologies can be tested among potential users. The field lab should be situated in a public place (for instance, a hospital) to make sure that everyone has access to the technologies. In addition to collecting input from users, the field lab could also function as a way of disseminating scientific developments and creating awareness among the general public. The stakeholders took some of the outcomes of the citizen consultation into account in their ideas for the field lab. For instance, the field lab could be used to engage citizens in the development of novel technologies and better consider the potential implications of nanotechnology. Furthermore, the stakeholders emphasized that the accessibility of the field lab for various publics should be ensured. The stakeholders were very positive about the discussion and felt they all could add their perspective. Furthermore, these stakeholders thought that this idea was relevant and novel, and they were more positive about this outcome than the stakeholders of the other workshops in the questionnaire and the evaluation interviews. However, none of the stakeholders took specific follow-up actions after the workshop.

**Findings based on the analysis of the co-creation workshops**

**Reflexivity**

Reflexivity is important for both a legitimate innovation process and added value to innovation. It is related to the willingness of scientists and innovators to open up their innovation trajectory to other stakeholder perspectives. With regard to the co-creation workshops, reflexivity refers to the willingness of scientists and innovators and other stakeholders to participate in the workshop and to reflect upon their daily practices related to innovation development. In every co-creation workshop, the participants showed a certain level of reflexivity, as they took the time to participate at the workshops and to reflect upon nanotechnology development for health. However, in the workshops that were connected to a specific innovation and a stakeholder perspective, which was the case in the diabetes workshop and the workshop on sensor technologies, stakeholders showed more reflexivity than in the workshop without a clear stakeholder perspective.

In the workshop on diabetes, the representatives of the two businesses showed their willingness to reflect upon their innovation by discussing it with other stakeholders. They were willing to present their technology during the workshops and were interested in suggestions. Similarly, in the workshop on sensor technologies, one of the researchers reflected upon her research project. In the workshop on policymaking, various policymakers were present, and they suggested ideas for better integrating societal needs and values in nanotechnology development, but none of them discussed or reflected upon their own daily practices. One of the policymakers explained: ‘it is difficult to voice opinions which do not match with the current practices of the organization we represent. There is little that I, as an individual, can do about it’.
Inclusion

Inclusion is an important condition for a legitimate innovation process and concerns the engagement of various stakeholders in the innovation trajectory. With regard to the co-creation workshops, inclusion requires an equal distribution of power among the participating stakeholders so that every participant can add value to the innovation based on his or her interests. From the analysis of the three co-creation workshops, it became clear that when there was a clear focus on an innovation and/or research, as was the case in diabetes and sensor workshop, it was difficult to treat all stakeholder perspectives equally. In both co-creation workshops, a clear starting point was chosen, which was introduced from a particular stakeholder perspective – the diabetes technologies were derived from the two businesses and the sensor technology was based on the project of one of the researchers. This stakeholder perspective led to specific discussions, which made it easy to connect the suggestions to existing technologies, but it came at cost of inclusiveness as it was only relevant for the particular stakeholder rather than the other participants.

In the co-creation workshop on diabetes, for instance, one of the researchers who was present at the workshop explained in the evaluation interview that for her, the workshop was not very relevant. She develops a technology for detecting biomarkers of diabetes type 2 in blood, but the discussion was mainly about the implementation of a diagnostic device and the data management plan. The CSO representative shared this opinion, stating in the evaluation interview: ‘I have the feeling that we indeed created something for the diagnostic device. Stakeholders with different backgrounds were brought together and created new insights. However, this was especially relevant for the CEO of the start-up working on the device and not for myself or my organization’.

Similarly, in the co-creation workshop on sensor technology, the business representatives thought that there was little added value for themselves as the focus of the debate was on the research process. For the post-doc researcher, however, the co-creation process was very relevant, as she obtained various insights for improving her line of research. She explained in the interview: ‘The co-creation workshop was a game-changer for me. The insights that were given by the different stakeholders pointed out relevant issues to take into account and raised relevant questions about potential applications and user groups’.

In contrast, the co-creation workshop on policy for nanotechnology was not presented from a specific stakeholder perspective. All stakeholders were free to come up with all ideas and suggestions, which led to a more inclusive co-creation process. Participants were more positive about the outcome of this workshop. A participating policymaker, for instance, said: ‘the workshop on policymaking and nanotechnologies is a good example of co-creation: With all participants we came to the idea of the field lab, which is a great and innovative idea to which every stakeholder contributed’. A participating citizen concluded: ‘It is important to have a mixture of experts and non-experts present in the co-creation process, and everyone should be treated as an equal partner (non-hierarchichal). This happened in our co-creation workshop when we jointly developed the idea of a field lab’. These findings indicate that inclusion is related to the openness of the workshop and that there is a trade-off between inclusion and specificity in the co-creation workshops that were organized.
Anticipation

The aim of the co-creation workshops was to align nanotechnology development with societal needs and values. This required a certain anticipation of stakeholders towards future applications and implications of the technology and taking into account the societal needs and values of future applications of nanotechnology that were defined in the citizen consultation. Based on the analysis of the three co-creation workshops, it became clear that anticipation was better possible in the application-oriented co-creation workshop, focusing on a later stage of technology development, than in the technology-oriented workshop, focusing on the early stage of technology development. The former was the case in diabetes, and the latter was the case in the workshop on sensor technologies. Furthermore, in the co-creation workshop without a specific orientation, as was the case in the workshop on policymaking, it was also possible to anticipate societal needs, as the participants brought in the application perspective during the workshop.

In the co-creation workshop on diabetes technology, stakeholders were able to anticipate future implications, and were able to connect them to the needs and values as defined during the citizen consultation. These future implications, values and needs could be easily connected to the products as they were application- and user-oriented and provided new insights. The business representative of the artificial pancreas stated in the evaluation interview: ‘The workshop uncovered some potential implications of our device regarding the ownership of data we hadn’t thought of yet’. It appeared to be much harder to connect the outcomes in the workshop on research for sensor technologies to citizens’ needs and values and future societal implications. In this context, deliberating the technology and research required specific technical knowledge, and participants who were not experts in the field of nanotechnology found it difficult to contribute to the debate. Furthermore, the suggestions were not connected to outcomes of the citizen consultation, as they were not considered relevant for the early developmental stage of the technology. For example, one of the scientists stated in the evaluation interview: ‘I don’t see any added value of including citizens in this co-creation process as the deliberation on the research project requires specific and technical knowledge’. In the workshop on policymaking, the stakeholders were also able to anticipate their suggestions based on societal needs and values, as they brought up the application-oriented perspective during the workshop. In this discussion, citizens’ needs and values were included. Furthermore, potential societal implications of the field lab were discussed. These findings indicate that anticipating future implications and taking into account citizens’ needs and values of future applications of nanotechnology is possible in workshops with an application-oriented perspective, often in a later stage of innovation.

Adaptation

The creation of added value to nanotechnologies requires the action of stakeholders along the value chain to adjust innovation (trajectory) based on societal needs and values, which is referred to as adaptation. Adaptation in the context of this research is the intentional or actual adjustment of research, product development, or policymaking by one or more stakeholders based on the outcomes of the co-creation workshops. The analysis of the three co-creation workshops showed that adaptation could be achieved if there was a problem owner among the stakeholders who felt responsible for the specific topic – technology and/or question – discussed in the workshop, as was the case in the
senor workshop. When none of the stakeholders felt responsible, which was the case in the diabetes and policymaking workshop, there was little intention among the stakeholders for follow-up actions. However, the three co-creation workshops did not start from a problem-oriented perspective, but the themes were decided based on interviews with experts, and the outcomes of the citizen consultation and the stakeholders were identified based on the themes, which made it difficult to find a problem-owner for each of the workshops.

For the co-creation workshop on diabetes, for instance, the question of the workshop was left relatively open, i.e. How can product development be improved based on societal needs and values? Although the outcomes were relevant for the business representatives, they did not (yet) implement the results of the co-creation workshop in their product development or had specific intentions for follow-up actions. The CEO of the company working on the early diagnostic device stated that their product was in the (early) developmental stage, and he did not (yet) see added value of integrating the implementation plan in the innovation process. The representatives of the company working on the artificial pancreas explained that they were about to get the certification for the artificial pancreas, and they did not want to change the functionality of the product at this stage. They thought it would have been more useful if the workshop focused on specific problems they encountered in the innovation process. One of the business representatives explained: ‘In the development of our technology, we are dealing with very specific problems, and I had the feeling that the co-creation activity was too general for that. The workshop would have been more useful if it would have been centred around our specific issues and challenges’.

After the co-creation workshop on research development for sensor technologies, the researcher took follow-up actions based on the outcomes of the workshop. The participants of the workshop suggested how to improve the researcher’s research, and as such, the research project was the main focus of the workshop and not the societal needs and values. Based on these suggestions, the researcher adjusted her research project, and she concluded: ‘The outcomes of the workshop gave me concrete guidelines on how to proceed with my research and provided insights in the next steps to take’. More specifically, the post-doc researcher explained that she used the outcomes of the workshop for a new research proposal to attract extra funding for labelling the proteins and that she agreed upon a collaboration with one of the scientists who was present at the workshop to explore opportunities for studying tumour cells and to get access to his laboratory equipment. She had not thought of the importance of these steps before the workshop. In the workshop on policy making, the theme was left open, and there was no stakeholder perspective connected to the workshop, which made adaptation even more difficult than in the diabetes workshops. Although all participants were positive about the idea of the field lab, there was no stakeholder who felt responsible for it and took any follow-up actions after the workshop. A policymaker who was present at that workshop explained in the evaluation interview: ‘Everyone was enthusiastic about the idea of the field lab. However, the roles of the different participants were not specified, and no further action was taken. It would be good to specify these roles during the co-creation workshop and define steps for valorisation and implementation’. These findings indicate that adaptation requires a sense of problem ownership among the participating stakeholders, which can be easier achieved in a workshop that includes a stakeholder perspective and focuses on a specific problem or challenge.
Discussion

Main findings

The experiences in the three workshops suggest that there are several challenges related to reflexivity, inclusion, anticipation and adaptation when setting up co-creation in support of RRI (see Table 2). The diabetes workshop was reflexive, as there was a clear innovator’s perspective included. Furthermore, it was easy to anticipate potential impacts of the discussed products because the workshop was application oriented and stakeholders discussed the implementation and use of the products. However, the workshop was only partly inclusive because the workshop was presented from a specific stakeholder perspective. Furthermore, adaptation played no role based on the outcomes of the workshop, as none of the stakeholders took any follow-up actions or intended to use the outcomes in the further development of the products. Therefore, it can be concluded that this workshop was partly legitimate and led to little added value of the innovation.

The outcomes of the workshop on research on sensor technologies for detecting cancer were reflexive but did not include any societal needs and values because it was difficult to anticipate the potential impacts in a technology-oriented workshop. Additionally, this workshop was not very inclusive: mainly scientists were present at the workshop, and those were the only actors who were able to substantially contribute to the research development. Furthermore, due to the specific stakeholder perspective, the workshop was most relevant for one particular scientist and less relevant for the other stakeholders. This scientist adapted the research trajectory based on the outcomes of the co-creation workshop. Thus, this workshop created added value to the innovation but did not lead to a legitimate innovation trajectory.

The workshop on policymaking for nanotechnologies was only partly reflexive since stakeholders reflected upon policy making in general, but none of the stakeholders included reflection upon their daily practices. The workshop was inclusive because all stakeholders operated on the same level due to the open character of the workshop. They were all equally responsible for the outcome of this workshop. Additionally, the outcomes anticipated future implications and societal needs and values. However, none of the stakeholders took further action after the co-creation workshop. Therefore, this workshop can be considered legitimate, but no added value of the innovation was created.

Co-creation to foster RRI aims for both a legitimate innovation trajectory and added value to the innovation. In theory, both Von Schomberg (2012), in his definition of RRI, and Voorberg, Bekkers, and Tummers (2015), in their definition of co-creation, emphasized that there is a need for mutual responsibility or collaboration to create a legitimate innovation process and created added value to the innovation or product. However, in
practice, we found that it is difficult to create this responsibility, and there is a trade-off between both aims. To add value to the innovation itself, there is a need for a certain level of adaptation, which can be achieved through specificity, in terms of focusing on a specific technology or product, and by having a clear action-oriented perspective. The latter can be gained by connecting the subject of the co-creation workshop to the work of a particular stakeholder. However, this comes at the cost of inclusion, which is needed for a legitimate innovation trajectory, because it gives the stakeholder a certain power over the other stakeholders. Earlier research has already concluded that an inclusive and adaptive innovation process inevitably leads to the question of power (Jarmai and Vogel-Pöschl 2020; Stilgoe, Owen, and Macnaghten 2013). There are always agencies that initiate and facilitate co-creation, and there is action needed from relevant actors for taking up the outcomes of the co-creation activity. This predefined ownership might influence the distribution of power and thereby negatively influence the collaboration between stakeholders in the co-creation process (Jarmai and Vogel-Pöschl 2020).

Furthermore, we found that adaptation is easier to achieve in an early developmental stage of the technology, as there is still room for adjustment than in a later stage, and anticipating societal needs values is easier in an application-oriented workshop. This finding is in line with the Collingridge dilemma or the dilemma of control, meaning that at the start of the innovation process, there is often insufficient knowledge about the trajectory and the implications of the innovation, but the innovation can be easily adjusted. At a later stage of innovation, impacts can be more easily predicted, but it is more difficult to adjust innovation, often due to limited resources (Genus and Stirling 2018; Owen, Macnaghten, and Stilgoe 2012).

**Theoretical contributions**

Our findings align with the conclusions of Delgado, Kjolberg, and Wickson (2011), who detected a gap between theory and practice of public engagement based on various tensions. The most fundamental tension they found was related to rationales or aims of public engagement, which they described as instrumental, substantive or normative. Public engagement exercises with an instrumental rationale aim to achieve a particular predefined end, a substantive rationale focuses on innovation development, and a normative rationale implies that public engagement will lead to increased legitimacy. The authors emphasized that tensions between the rationales particularly arise when exercises have been theoretically argued for according to one rationale (e.g. substantive) but then were designed, enacted and/or evaluated according to another (e.g. normative) (Delgado, Kjolberg, and Wickson 2011). Stirling (2008) found that the tensions between the normative and substantial rationale are closely related to democratic openness and technocratic closure. An open co-creation process in which various stakeholders have an equal say is inclusive and therefore legitimate (normative aim) but does not necessarily lead to adaptation of the innovation (substantive aim). Indeed, our findings indicate that, in theory, co-creation as a means for RRI is based on a normative and substantive rationale, but in practice, it is difficult to achieve both aims as there is a trade-off between inclusion and anticipation – related to democratic openness – and adaptation – related to technocratic closure. It may seem tempting to focus mainly on technological closure for the sake of innovation development, but some scholars (Jasanoff 2014; Rowe and Frewer 2005;
Wynne (2006) argued that this technological closure should not become a goal in itself. This would lead to an instrumental objective of co-creation and could be a lost opportunity for including different perspectives in the development of the innovation, thereby overlooking societal needs and values. However, solely focusing on the inclusion of these different perspectives might be a lost opportunity as well. It requires a pro-active approach of stakeholders to adapt the innovation process (Foley, Wiek, and Kay 2017), for which a sense of ownership is required.

Instead of trying to integrate all rationales in co-creation for RRI, it would be better to acknowledge that co-creation can come in different forms. Based on previous literature and our findings, we can distinguish three different types of co-creation: co-creation as a tool for including different types of audiences in the innovation process (c.f. Polk 2015); co-creation as a tool for anticipating societal needs and values in the innovation trajectory (c.f. Gudowsky and Sotoudeh 2017; Mauser et al. 2013); and co-creation for adapting the innovation based on suggestions from different types of publics as a tool for innovation development (c.f. Van de Grift, Cuppen, and Spruit 2020; Von Hippel 2005).

**Limitations and suggestions for future research**

This research, however, does have some limitations. An important limitation is that the findings of our study are based on an analysis of only three co-creation workshops. This qualitative methodology provided us with the opportunity for an in-depth analysis and evaluation of the different characteristics of the co-creation workshops on the various dimensions of RRI. However, we should take this small number into account when generalizing and interpreting the results. For future research, it would be interesting to analyse multiple co-creation configurations based on the outcomes of this study, thereby providing a more systematic analysis.

Second, the setup of the co-creation workshops was based on the methodology designed within the H2020-project GoNano, and there was no clearly defined need for the co-creation sessions. Instead, the themes and application areas were selected based on expert interviews, the outcomes of the citizen consultation, interviews with key stakeholders, and the stakeholders who were able and willing to participate in the co-creation workshops. This influenced the outcomes and follow-up actions of the workshop, as described in the results section. It will be interesting to study a problem-oriented co-creation session in future research, in which a specific problem or challenge of a stakeholder is used as the starting point and stakeholders connected to this problem are being invited to the workshop.

Third, not every co-creation workshop involved the same type of stakeholders. In the co-creation workshop on sensor technologies, no citizens or policymakers were present, and in the workshop on policymaking for nanotechnology and health, there was not a representative of a CSO present. Although the aim was to come to a mixture of different stakeholders per session based on a normative stakeholder approach, there were some stakeholders who cancelled last-minute.

**Conclusion**

This study contributes to insights into co-creation as a tool for responsible research and innovation. Co-creation comes in different forms and shapes in terms of openness and
specificity, developmental stage of the discussed innovation, and the presence or absence of a stakeholder- and action-oriented perspective. The results of this study show that the design of the co-creation methodology influences how it supports the different RRI dimensions of reflexivity, inclusion, anticipation, and adaptation. Based on these dimensions, a trade-off can be detected between creating legitimacy and creating added value. Instead of integrating both aims when setting up a co-creation workshop, to focus on a specific aim is recommendable. There is not one aim better than the other, because they touch upon different RRI dimensions. However, it is important to clearly predefine the aim, be transparent about it when organizing the event, and to take into account the design of the workshop that suits this aim.

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References

Contera, S., J. B. de la Sema, and T. D. Tetley. 2020. “Biotechnology, Nanotechnology and Medicine.” Emerging Topics in Life Sciences 4: 551–554. doi:10.1042/ETLS20200350.

De Jong, M. D. T., S. Neulen, and S. R. Jansma. 2019. “Citizens’ Intentions to Participate in Governmental Co-creation Initiatives: Comparing Three Co-creation Configurations.” Government Information Quarterly 36 (3): 490–500. doi:10.1016/j.giq.2019.04.003.

Delgado, A., K. L. Kjolberg, and F. Wickson. 2011. “Public Engagement Coming of Age: From Theory to Practice in STS Encounters with Nanotechnology.” Public Understanding of Science 20 (6): 826–845. doi:10.1177/0963662510363054.

Engels, F., A. Wentland, and S. M. Pfopenhauer. 2019. “Testing Future Societies? Developing a Framework for Test Beds and Living Labs as Instrument for Innovation Governance.” Research Policy 48: 103826–103837. doi:10.1016/j.respol.2019.103826.

European Commission. 2016. “Public Engagement in Responsible Research and Innovation.” https://ec.europa.eu/programmes/horizon2020/en/h2020-section/publicengagementresponsible-research-and-innovation.

Foley, R. W., M. J. Bernstein, and A. Wiek. 2016. “Towards an Alignment of Activities, Aspirations, and Stakeholders for Responsible Innovation.” Journal of Responsible Innovation 3 (3): 209–232. doi:10.1080/23299460.2016.1257380.

Foley, R., A. Wiek, and B. Kay. 2017. “Nanotechnology Development as If People and Places Matter.” NanoEthics 11 (3): 243–257. doi:10.1007/s11569-017-0300-y.

Genus, A., and A. Stirling. 2018. “Collingridge and the Dilemma of Control: Towards Responsible and Accountable Innovation.” Research Policy 47 (1): 61–69. doi:10.1016/j.respol.2017.09.012.

Gudowsky, N., and W. Peissl. 2016. “Human Centred Science and Technology – Transdisciplinary Foresight and Co-creation as Tools for Active Needs-Based Innovation Governance.” European Journal of Futures Research 4 (8): 1–10.

Gudowsky, N., and M. Sotoudeh. 2017. “Into Blue Skies – A Transdisciplinary Foresight and Co-creation Method for Adding Robustness to Visioneering.” Nanoethics 11: 93–106. doi:10.1007/s11569-017-0284-7.

Ienca, M. 2019. “Democratizing Cognitive Technology: A Proactive Approach.” Ethics and Information Technology 21: 267–280. doi:10.1007/s10676-018-9453-9.

Ind, N., and N. Coates. 2013. “The Meanings of Co-creation.” European Business Review 25 (1): 86–95. doi:10.1108/09555341311287754.

Jansma, S. R., A. M. Dijkstra, and M. D. T. de Jong. forthcoming. “How can I Contribute? Citizen Engagement in the Development of Nanotechnology for Health.” Nanoethics.

Jantan, R., N. Kamaruddin, S. Z. Abidin, T. S. Said, and H. Ramli. 2020. “Value in Exchange: The Importance of User Interaction as the Center of Experiences. International Journal of Innovation.” Creativity, and Change 11: 75–83.

Jarmai, K., and H. Vogel-Pöschl. 2020. “Meaningful Collaboration for Responsible Innovation.” Journal of Responsible Innovation 7 (1): 138–143. doi:10.1080/23299460.2019.1633227.

Jasanoff, S. 2014. “A Mirror for Science.” Public Understanding of Science 23 (1): 21–26. doi:10.1177/0963662513505509.
Malakhatka, E., L. Sopjani, and P. Lundqvist. 2021. “Co-creating Service Concepts for the Built Environment Based on the End-Users’ Daily Activities Analysis: KTH Live-in-lab Explorative Case Study.” *Sustainability* 13: 1942–1963. doi:10.3390/su13041942.

Mauser, W., G. Klepper, M. Rice, B. S. Schmalzbauer, H. Hackmann, R. Leemans, and H. Moore. 2013. “Transdisciplinary Global Change Research: The Co-creation of Knowledge for Sustainability.” *Current Opinion in Environmental Sustainability* 5: 420–431. doi:10.1016/j.cosust.2013.07.001.

Metselaar, J. M., and T. Lammers. 2020. “Challenges in Nanomedicine Clinical Translation.” *Drug Delivery and Translational Research* 10: 721–725. doi:10.1007/s13346-020-0007405.

Owen, R., P. Macnaghten, and J. Stilgoe. 2012. “Responsible Research and Innovation: From Science in Society to Science for Society, with Society.” *Science and Public Policy* 39: 751–760. doi:10.1093/scipol/scs093.

Polk, M. 2015. “Transdisciplinary co-Production: Designing and Testing a Transdisciplinary Research Framework for Societal Problem Solving.” *Futures* 65: 110–122. doi:10.1016/j.futures.2014.11.001.

Prandelli, E., G. Verona, and D. Raccagni. 2006. “Diffusion of Web-Based Product Innovation.” *California Management Review* 48 (4): 109–135.

Reed, M. S., S. Vella, E. Challies, J. de Vente, L. Frewer, D. Hohenwallner-Ries, T. Huber, et al. 2018. “A Theory of Participation: What Makes Stakeholder and Public Engagement in Environmental Management Work?” *Restoration Ecology* 26 (1): S7–S17. doi:10.1111/rec.12541.

Rip, A. 2014. “The Past and Future of RRI.” *Life Sciences, Society and Policy* 10: 1–15. doi:10.1186/s40504-014-0017-4.

Roberts, N. 2004. “Public Deliberation in an Age of Direct Citizen Participation.” *The American Review of Public Administration* 34: 315–353.

Robinson, D. K. R., A. Simone, and M. Mazzonetto. 2020. “RRI Legacies: co-Creation for Responsible, Equitable, and Fair Innovation in Horizon Europe.” *Journal of Responsible Innovation*.

Rowe, G., and L. J. Frewer. 2005. “A Typology of Public Engagement Mechanisms.” *Science, Technology, & Human Values* 30 (2): 251–290.

Russel, A. W. 2013. “Improving Legitimacy in Nanotechnology Policy Development Through Stakeholder Engagement: Forging new Pathways.” *Review of Policy Research* 30 (5): 566–587. doi:10.1111/ropr.12037.

Shelley-Egan, C., D. M. Bowman, and D. K. R. Robinson. 2018. “Devices of Responsibility: Over a Decade of Responsible Research and Innovation Initiatives for Nanotechnologies.” *Science and Engineering Ethics* 24 (6): 1719–1746. doi:10.1007/s11948-017-9978-z.

Silverman, R. M., H. L. Taylor, L. Yin, C. Miller, and P. Buggs. 2019. “Are We Still Going Through the Empty Ritual of Participation? Inner-City Residents and Other Grassroots Stakeholders’ Perceptions of Public Input and Neighborhood Revitalization.” *Critical Sociology* 46 (3): 413–428. doi:10.1177/0896920519837322.

Stilgoe, J., R. Owen, and P. Macnaghten. 2013. “Developing a Framework for Responsible Innovation.” *Research Policy* 42 (9): 1568–1580. doi:10.1016/j.respol.2013.05.008.

Stirling, A. (2008). “‘Opening Up’ and ‘Closing Down’: Power, Participation, and Pluralism in the Social Appraisal of Technology.” *Science, Technology, & Human Values* 33 (2): 262–294. doi:10.1177/0162243907311265.

Van de Graaf, E., C. Cuppen, and S. Spruit. 2020. “Co-creation, Control or Compliance? How Dutch Community Engagement Professionals View Their Work.” *Energy Research & Social Science* 60: 101323–101337. doi:10.1016/j.erss.2019.101323.

Vargo, S. L., and R. F. Lusch. 2004. “The Four Marketing Myths: Remnants of Goods-Based, Manufacturing Model.” *Journal of Service Research* 6 (4): 324–335. doi:10.1177/1094670503262946.

Von Hippel, E. 2005. *Democratizing Innovation*. Cambridge, MA: MIT Press.

Von Schomberg, R. 2012. “Prospects for Technology Assessment in a Framework of Responsible Research and Innovation.” In *Technikfolgen Abschätzen Lehren: Bildungspotenziale Transdisziplinärer*, edited by M. Dusseldorp and R. Beecroft, 39–61. Wiesbaden: VS Verlag für Sozialwissenschaften.
Voorberg, W. H., V. J. J. M. Bekkers, and L. G. Tummers. 2015. “A Systematic Review of Co-creation and Co-production: Embarking on the Social Innovation Journey.” *Public Management Review* 17 (9): 1333–1357. doi:10.1080/14719037.2014.930505.

Wynne, B. 2006. “Public Engagement as a Means of Restoring Public Trust in Science: Hitting the Notes, but Missing the Music?” *Community Genetics* 9 (3): 211–2020.

Yoo, D., A. Huldtgren, J. P. Woelfer, D. G. Hendry, and B. Friedman. 2013. “A Value Sensitive Action-Reflection Model: Evolving Co-design Space with Stakeholder and Designer Prompts.” In CHI 2013 Conference: Changing Perspectives, 419–428. Paris. https://vsdesign.org/publications/pdf/p419-yoo.pdf.