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DOI
10.1016/j.jrt.2023.100071

Publication date
2023

Document Version
Final published version

Published in
Journal of Responsible Technology

Citation (APA)
Kroesen, M., Vermaas, P., van de Poel, I., & Griesdoorn, F. (2023). The presence of Responsible Research and Innovation in the perspectives of Dutch policy officers regarding innovation with quantum technology. *Journal of Responsible Technology*, *16*, Article 100071. https://doi.org/10.1016/j.jrt.2023.100071

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Journal of Responsible Technology 16 (2023) 100071

Contents lists available at ScienceDirect

Journal of Responsible Technology

journal homepage: www.sciencedirect.com/journal/journal-of-responsible-technology

The presence of Responsible Research and Innovation in the perspectives of Dutch policy officers regarding innovation with quantum technology

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ARTICLE INFO

Keywords:
Responsible research and innovation
Quantum technology
Q-method
Dutch governmental policies
Horizon 2020
Horizon Europe
European Union

ABSTRACT

The European Union strives to align research and innovation to the values, needs and expectations of society to address societal challenges. To support this alignment the European Union endeavours to make Responsible Research and Innovation (RRI) part of the governmental policies on science and technology of its member states. If the European Union is effective in this endeavour, then principles that are common in the field of RRI should play a significant role in the perspectives that belong to the member states' policy officers for research and innovation. In this paper we empirically check this by conducting a Q-method study on Dutch policy officers working on quantum technology-related policies. In this study we found four perspectives on innovation among these policy officers. In all these perspectives some of the RRI principles are present in merely a weak manner, or even absent, casting substantial doubts on whether RRI has become part of the EU member state governmental policies on science and technology.

1. Introduction

The European Union has embedded Responsible Research and Innovation (RRI) into its key research funding programmes like Horizon 2020 and Horizon Europe to support the alignment of research and innovation to the values, needs and expectations of society to address societal challenges (EU Horizon Europe, 2022). These programmes facilitate collaboration and strengthen the impact of research and innovation in developing, supporting, and implementing European Union's policies while tackling global challenges (EU Horizon Europe, 2022). Member state policy officers are informed on these programmes in bilateral and multilateral meetings, events, and publications (EU Horizon Europe, The next EU, 2022). As a result of embedding RRI, one would expect that the principles of RRI surface in the perspectives of the policy offers in respective European countries engaged with policies regarding research and innovation, but it is not a given. Up until this study, the extent in which RRI principles are present in the perspectives of policy officers remained undiscovered.

In the Netherlands, a policy officer influenced by the (national) political discourse, public opinion, business lobbying, scientific findings, innovation, non-governmental organizations, and other societal topics of interest, will develop an individual perspective on innovation. The policy officer uses this individual perspective in a process with other policy officers' perspectives to create or adjust policies based on consensus. That consensus is based on a combined and shared perspective, this sparked our interest and lead us to the following questions: To what extent are RRI principles part of Dutch policy officers' shared perspectives? What challenges and benefits do the Dutch policy officers shared perspectives bring? Because of our questions, we needed a method that combines quality and quantity to find shared perspectives.

We have chosen to use the Q method because it is unique in the sense that it defines perspectives as the subjective opinions or ideas that a group has on a subject (Brown, 1986) and uses the individual's self-reference to find these perspectives. The Q method finds shared perspectives based on consensus on a statement and that relates to the way Dutch policy officers create or adjust policies. We have focused on Dutch policy officers involved in the development of quantum technology under the assumption that the Netherlands is a technological advanced member of the EU which is intensively investing in quantum technology (Government Allocates, 2021). Moreover, quantum technologies have potentially large societal implications and may eventually underlie a whole new technological infrastructure, as much as the semiconductor revolution changed everything in last half of the 20th century" (Raymer & Monroe, 2019).

A second reason for focussing on Dutch policy officers is that the Netherlands has launched a large national programme for developing quantum technologies with an ambition to lead Europe in the

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https://doi.org/10.1016/j.jrt.2023.100071

Available online 29 October 2023
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development of the necessary social, ethical, legal frameworks aiming at solutions for societal challenges. Both the National Agenda for Quantum Technology (Quantum Delta, 2019) as the Quantum Delta programme (Quantum Delta Programme, 2023) suggest a strong RRI approach, and this relates to funds allocated from the Horizon programmes, which have RRI embedded as regulations or objectives. The strong RRI approach is supported by the Dutch government, as they funded the Quantum Delta programme based on their proposal for the national growth fund (Nationaal Groeifonds, 2023). As a result of embedding RRI into the European Union's key research funding programmes, the substantial national attention for research and innovation with quantum technology and the ambitions of the Quantum Delta programme, one would expect that Dutch policy officers involved in governmental policies on science and technology have adopted RRI principles in their perspectives on research and innovation with quantum technology. In this paper we assess this expectation, focusing on Dutch policy officers working on quantum technology-related policies. We present a Q-method study that found four perspectives amongst these policy officers. These perspectives show that some of the main RRI principles are absent or present in a weak manner, casting substantial doubt on whether RRI has become part of the perspectives of EU member states' governmental policy officers working on policies for science and technology.

Our main question, what are the shared perspectives of Dutch policy officers regarding innovation with quantum technology and to what extent are RRI principles part of these perspectives? Had us venture to answer questions that became building blocks of this study. Those are: What may be guiding principles that are shared amongst the different academic views on RRI? Were Dutch policy officers informed on RRI and if so, how? What is of interest, for this study, regarding innovation with quantum technology? How may we find policy officers' shared perspectives? How can we assess if RRI is part of policy officers' shared perspectives? And what challenges and benefits do we expect these shared perspectives bring?

We organized this paper as follows. Section 2 starts with a theoretical background. It presents RRI and establishes the RRI principles we use in this study that enabled us to assess if RRI is part of the perspectives of the policy officers. This section also sketches the efforts by the European Union for making RRI part of its research policies, and briefly introduces quantum technologies. Section 3 describes the Q method and the way we applied in this study. We give the results of our study in Section 4 and the paper ends with drawing conclusions and a discussion of the outcomes.

2. Theoretical background

2.1. Responsible research and innovation

To establish RRI principles we did a literature study on Responsible Research an Innovation, focusing on the last two decades in which RRI has become an emerging scientific field of research and a central approach to research and innovation in Europe. Although RRI has become increasingly important, there is no definition of RRI that is agreed upon, and there is no clear way to implement RRI. We discovered that there are several common themes in RRI. To avoid repetition of similar academic views our literature study selected specific literature that highlights possible RRI principles and clarifies them. During the study we found the argument that RRI should be understood as a strategy of stakeholders to become mutual responsive to each other and anticipate research and innovation outcomes underpinning "the grand challenges" of our time, for which they share responsibility (Von Schomberg, 2013). An alternative view is that RRI is a policy driven discourse that emerged in the early part of the last decade from the European Commission (Owen & Pansera, 2019) that aims to foster the design of inclusive and sustainable research and innovation, with an emphasis on co-creation and co-production with society. In this second view RRI strives to align research and innovation to the values, needs and expectations of society, and emphasizes the focus on societal grand challenges. In addition to the first and second view on RRI, it is argued that stakeholder inclusion, participation, and partnership, leads to harmony, consensus and fundamentally reduces different stakeholders' judgments and value frames to a common ground (Blok, 2019). When involved in a dialogue on innovation, it is suggested that the conversational partner requests ethical behaviour in this dialogue. This involves a response shift from "primarily understanding" to "actual ethical behaviour." For Dutch policy officers that would amount to adjusting policies or rethinking policies to accommodate the conversational partners interests and investigating that and adjustment of policies does not harm the interests of other stakeholders.

Another subject in the academic field of RRI is design for value. It is an important act to instil values into a design and it entails the translation of values into design requirements (Van de Poel, 2013). However, there is a problem that engineers are often confronted with, moral dilemmas in their design work because of conflicting value requirements. As a result of this, values may be traded off for other values, when designing a technology or innovation (Van den Hoven, Lokhorst & van de Poel, 2012). For every design this leads to a conundrum, how to prioritize conflicting value requirements? There may be an answer in the suggestion for the concept of 'responsibility by design.' It is intended to encapsulate the idea of embedding RRI in research and innovation in a way that makes it part of the fabric of the resulting outcomes (Stahl et al., 2021). This may contribute to solving conflicting value requirements, however addressing responsibility for innovation outcomes is a multi-faceted challenge in society. Responsibility is shared by the researchers studying it, the inventors creating it, policy officers that introduce law, regulations, and policies to guide it, citizens that wield the innovation to suit their desires and many other actors.

On top of these engineering challenges there is the argument that technological change "heats up" morality into ethics and new technologies have the potential to destabilize parts of our tacit, implicit morality and thus turn them into topics for explicit ethical reflection, debate, and struggle (Swierstra, 2015). It is uncertain if Dutch policy officers are familiar with these challenges and take account of it. In this study we refer to the awareness of these challenges as "understanding the principle that technology destabilizes our morality."

Finally, responsible innovation is viewed as a system that has a framework that uses anticipation, inclusion, reflexivity, and responsiveness as principles. (Stilgoe, Owen & Macnaghten, 2013) And it is argued that anticipatory governance may not be complete solutions to our woes in governing technology, but they certainly can contribute to bending the long arc of technoscience more toward humane ends. (Guston, 2014) in our contemporary society one may argue that anticipation from a governmental level may be a decisive factor for an innovation approach.

Based on this theoretical background, we extracted and selected principles of RRI, that we take as shared amongst the different academic views on RRI, to enable us to assess if RRI is part of the perspectives of policy officers. We must note that design for value is recognized as one of the principles of RRI, However, this study is aimed at Dutch policy officers regarding innovation with quantum technology and in their work, they do not engage in the act of designing. As a result, the principles used in this study are anticipation, inclusiveness, reflexivity, responsiveness, co-creation & co-production, sustainability, and the understanding that new technology destabilizes our morality.

- *Anticipation* is in the context of RRI explained as a promissory narrative of expectation because of foresight, technology assessment and scenario development (Von Schomberg & Hankins, 2019). As this narrative arises from foresight, technology assessment and scenario development, it is as much an act as a narrative, in which one tries to describe and analyse future impacts of innovation by articulating multiple future possibilities and consequences that arise from innovation.

- *Inclusiveness* is an aspect of RRI that refers to finding, engaging, and inviting actors to a discourse on the process and the subject of innovation. These actors should be from diverse backgrounds and represent society. It is presented as having a primary objective to obtain values and have civil society assert and contest the values that are affected by innovation or introduced by innovation (Von Schomberg & Hankins, 2019).
- *Reflexivity* is an act of hindsight in which an actor or group of actors explore the outcome of an innovation or innovation process and compare it with earlier expectations. The International Handbook of Innovation articulates the need to avoid myopathy by asking other stakeholders to participate and appeals for intellectual honesty from the actor or group of actors engaged in the act of reflection (Von Schomberg & Hankins, 2019).
- *Responsiveness* entails the actual shift from moral intellectual understanding towards acting ethically (Blok, 2019). This means that one does something with the insight the conversational participating actor gives. Where other RRI principles (e.g., anticipation, inclusiveness, reflexivity, co-creation & co-production) give an intellectual understanding of an innovation or innovation process, being responsive to this intellectual understanding is to act upon it in an ethical manner. It is important to note that the principles mentioned give more than just an intellectual understanding, however, to understand responsiveness it is necessary to understand the direct relation between the other principles and being responsive.
- *Co-creation & Co-production* is the cooperation of multiple stakeholders in an innovation process, aligning various ideas, disciplines, expertise, interests, and values. When an innovation is mature enough, co-production is the cooperation of multiple stakeholders that move the innovation towards an upscaled production and delivery towards the market and increases the availability of the innovation (Von Schomberg & Hankins, 2019).
- *Sustainability* is research and innovation which meets the needs of the present without compromising the ability of future generations to meet their own needs. Sustainable research and innovation therefore require environmentally protective activities and respect for health and safety issues as well as the care and responsiveness for the future. It is stated that innovation cannot achieve full sustainability (Von Schomberg & Hankins, 2019), still it is an ethical principle towards innovation and the innovation process.
- *New technology destabilizes our morality* refers to the effect of the introduction of new technology on our morals (Swierstra, 2015). Humans do not singularly decide what to do with a new technology, but the technology itself indicates what a human can do with it. Like a hammer shaping the thinking of a carpenter, a brush shaping the thinking of a painter and a mobile phone shaping its communicator.

After we selected these seven principles based on different shared academic views on RRI we set out to find if and how Dutch policy officers were informed on RRI.

2.2. Responsible research and innovation in the EU

In the Netherlands we did not find a Dutch program that specifically targets the Dutch policy officers informing them on RRI, however the Netherlands is a member state of the European Union, and its policy officers were informed on RRI by the European Union. The European Union incorporated RRI into its key research funding programmes like Horizon 2020 and Horizon Europe (EU. Horizon Europe, 2022) and communicated about the programmes to the EU member states, in for instance the Netherlands the programmes are included in the *Subsidie- en financieringswijzer* from the *Rijksdienst voor ondernemend Nederland* (RVO. Horizon Europe Onderzoek en Innovatie, 2022).

The programmes facilitate collaboration and strengthens the impact of research and innovation in developing, supporting, and implementing European Union's policies while tackling global challenges (EU. Horizon Europe, 2022). These policies affect member states and local governance within the European Union and are expected to be followed up by a change in member state policies, regulations, or laws.

For example, within Horizon Europe the presence of RRI is embedded in these regulations and objectives:

- Regulation Horizon Europe, Article 2 - Recital (26): the programme should engage and involve citizens and civil society organizations in co-designing and co-creating responsible research and innovation (RRI) agendas and contents that meet citizens' and civil society's concerns, needs and expectations.
- Regulation programme principle (A6a.8): The programme shall promote co-creation and co-design through engagement of citizens and civil society.
- Horizon Europe, Specific programme; Operational objectives (A2.2): (c) promoting responsible research and innovation, taking into account the precautionary principle; (n) Improving the relationship and interaction between science and society, including the visibility of science in society and science communication, and promoting the involvement of citizens and end-users in co-design and co-creation processes.
- Open Science, which includes practices such as citizen and societal engagement, is embedded throughout the programme: within topics, award criteria for proposal evaluation, monitoring, reporting requirements and key impact pathway indicators.

In the Netherlands, some of the policy officers have been tasked to follow these programmes and help organizations and businesses to apply for programme funds (RVO. Horizon Europe Onderwerpen en Adviseurs, 2022).

Now that we have explored how Dutch policy officers were informed on RRI, its necessary to understand what is of interest to this study regarding innovation with quantum technology.

2.3. Quantum technology

Innovation with quantum technology is based on quantum theory and is indicated to follow the revolutionary path of the semiconductor technologies. "Quantum technology is outlined as exploiting the unique quantum features of superposition, entanglement, and fundamental metrology metrics to create new opportunities in secure communication, high-precision sensing, and revolutionary computers. Quantum technology may eventually underlie a whole new technological infrastructure, much as the semiconductor revolution changed everything in last half of the 20th century" (Raymer, 2019). Furthermore, quantum technology is indicated as an important part of the future in which we solve major societal problems (Quantum Delta, 2019).

These descriptions give the impression that quantum technology is a technology with potentially large societal implications and might address contemporary societal challenges, such as the energy transition. Understanding this significant impact on society one might anticipate that innovations with quantum technology have impact on Dutch policy officers' policies and is a subject that is on the Dutch governmental agenda. Therefore, quantum technology is one of the subjects of innovation, which is useful to assess the expectation that policy officers of member states involved in governmental policies on science and technology have adopted the principles of RRI in their perspectives on research and innovation.

In Europe, since 2018, a flagship initiative is in place (Quantum Flagship, 2022) with a long-term vision to develop a so-called quantum internet, where quantum computers, simulators and sensors are interconnected via quantum communication networks. The next phase of the Quantum Flagship is funded under Horizon Europe and has started. It is expected to fund one billion euro. It consolidates and expands European research leadership in quantum technologies and brings research results closer to industrial exploitation.

In the United States of America, the National Quantum Initiative (NQI) Act was enacted in December 2018 to accelerate American leadership in quantum information science, spending 2.7 billion dollars from 2019 to 2022 and projects an additional eight hundred million dollars for 2023. (USA National Quantum Initiative, 2023)

In China, the most visible quantum technology is their Quantum Secure communication Networks. China's National Natural Sciences Foundation, and the Chinese Academy of Sciences (CAS) provide the funding for many of the other quantum technology areas. Additionally, CAS and the University of Science and Technology of China, with support from institutes all over China, are building a new National Laboratory for Quantum Information Science, aimed to become the world's largest quantum research facility, spending fifteen billion dollars through 2022. (Quantum Computing Report, 2023)

3. Research method

Having set the research questions, the theoretical background and context of this study, we set out to find a method that combines quality and quantity to find shared perspectives. As this study aims to find the shared perspectives of Dutch policy officers regarding innovation with quantum technology, the Q method is particularly suitable because, firstly, the Q method reveals subjective viewpoints on a topic (Brown, 1986) and, secondly, it proceeds from the idea that one can find perspectives that are shared across stakeholders (Wolbertus, Jansen & Kroesen, 2020). These subjective viewpoints and shared perspectives are derived from statements that are ranked. We chose statements that included RRI and other principles to establish which are present or absent in the shared perspectives of the Dutch policy officers. The Dutch policy officers were not informed about the statements that included RRI principles to avoid biased answers. The TU Delft Human Research Ethics Committee (HREC) approved the study and the study complied with the TU Delft guidelines for informed consent.

This study followed a Q method-based procedure consisting of four steps:

1 Build up a concourse consisting of a set of statements and select specific statements*.
2 Select respondents and have them rank the selected statements.
3 Do a factor analysis on the ranked statements.
4 Interpret the found perspectives.

*The selection of specific statements is called a Q-set in the Q-method.

3.1. Build up a concourse

In the first step a concourse was build consisting of a set of statements on innovation with quantum technology. We built the set of statements upon the principles derived from our literature study on RRI, Quantum technology and a survey on innovation with quantum technology, the Dutch National Agenda on Quantum Technology (Quantum Delta, 2019), internal and external policy documents from the Dutch government (EZK innovatiebeleid, 2021 and EZK kamerbrief quantum, 2020), interviews about quantum technology with Dutch policy officers (during 2019/2020) and meetings with the *Quantum Innovation Hub Rijksoverheid* (From 2018 to 2020).

The *Quantum Innovation Hub Rijksoverheid* is a part of the *Rijks Innovatie Community*. The community is an initiative to connect policy officers within the governmental ministries and agencies to work together and address challenges that are multidisciplinary and come from the field of innovation. The *Quantum Innovation Hub Rijksoverheid* is a group that adjoined the community and is especially interested in quantum technology, this hub includes members of the scientific and business community. This resulted in a concourse of two hundred statements. Drawn from the theoretical background, we extracted seven common principles, these are: Anticipation, inclusiveness, reflexivity, responsiveness, co-creation &co-production, sustainability, and the principle that new technology destabilizes our morality as principles. We chose statements including or excluding these principles in our Q-set. A Q-set that has between forty and eighty statements is considered satisfactory (Watts & Stenner, 2005). We selected a Q-set consisting of forty-two statements.

3.2. Select respondents and rank the selected statements

In the second step respondents were selected and requested to rank the Q-set. Our criteria where:

- The respondents must work as a policy officer at a policy department at a Dutch ministry or a Dutch governmental agency.
- They need to address innovation in their work.
- They work on quantum technology-related policies.

We invited 81 Dutch policy officers working at the policy departments from all the Dutch ministries and agencies to rank our statements. These officers address innovation in their work: either they are responsible for innovation policies, or they adjust policies because of innovation, and they work on quantum technology-related policies. At the time of the study the Dutch Policy Officers were selected from the governmental address book or the interdepartmental "*Rijks Innovatie Community*" address book showing that they meet the criteria.

The set of forty-two statements was included in an online survey following the grid presented in Fig. 1, respondents were required to sort the statements on a scale from −5 (disagree) to +5 (agree). Within the Q-method this is called the Q-sorting task. Thirty-nine governmental policy officers responded positively and completed the Q-sorting task. Afterwards respondents were asked to motivate their responses.

3.3. Factor analysis

In line with guidelines for the Q-method, the result of the 39 Q-sorting tasks were subjected to a by-person factor analysis using a Principal Component Analysis, after which Varimax rotation was applied to achieve a simple structure. Solutions with different numbers of factors extracted (2–7) were explored. Based on the criterion introduced in Political Subjectivity, Applications of Q-methodology in political science, at least three persons should significantly load on a factor to identify a shared perspective (Brown, 1980). The 4-factor solution was considered optimal in this solution. 12, 10, 13 and 5 respondents were 'flagged' as factor exemplars of the respective factors (1–4).

To reveal the shared perspectives, factors scores were computed by averaging the result of the 39 Q-sorting tasks of the factor exemplars (weighted by their respective factor loadings). The resulting (standardized) scores were then recoded to the scores used in the original grid (Fig. 1). Hence the highest standardized factor score was recoded to +5, the next two highest scores to +4, and so on.

3.4. The interpretation of perspectives

In the fourth step, we used the factor scores to interpret each perspective. We have included comments, which were provided by the respondents, after the ranking task, which support the interpretation of the factors.

Each perspective shows scores on the statements (Fig. 1). The statements included or excluded RRI principles. For every principle, multiple statements were used to establish if that principle is part of the perspective.

The higher a group with a shared perspective scored on multiple statements including a principle, the more confidence we have that the principle has a moderate to strong presence in the shared perspective.

-5	-4	-3	-2	-1	0	1	2	3	4	5
statement	statement	statement	statement	statement	statement	statement	statement	statement	statement	statement
	statement	statement	statement	statement	statement	statement	statement	statement	statement	
		statement	statement	statement	statement	statement	statement	statement		
			statement	statement	statement	statement	statement			
				statement	statement	statement				
		<-- Disagree			statement			Agree -->		

Fig. 1. Adopted forced distribution for Q-sorting task.

The higher a group with a shared perspective scored on multiple statements excluding a principle, the more confidence we have that the principle has a weak to very weak presence or is absent in the shared perspective. In the interpretation and the outcome, we have considered, scores, that seem inconsistent, for example, agreeing with a statement on inclusiveness while also agreeing with a statement that excludes inclusiveness. In those cases, we analysed all the statements to discover explanations and in some circumstances the comments that were provided by the respondents gave an explanation.

For the interpretation we used the scores as followed:

In Table 2 we show how a respondent was able to score, how we assigned meaning to a specific score and how these were interpreted as an indication for the presence or absence of an RRI principle. Only multiple statements resulting in multiple presence indicators were used in chapter 5 of this paper to fill Table 3 showing the analysis per perspective group. We used the −1 and +1 scores in the interpretation only if they were accompanied by another score on a statement addressing the same principle. A neutral score was only used if it contributed towards insight on the shared perspective. We used negative statements as well, for those statements the score is considered as the opposite of the interpretation overview. For example, a statement as follows: it is not necessary to anticipate, if strongly agreed upon, would indicate that the principle 'anticipation' is absent.

4. Results & analysis

Thirty-nine policy officers responded to the invitation to rank the Q-set. After the analysis we discovered four groups that have cohesive perspectives within their group. Table 1 presents an overview of the four groups we found and their respective scores on the forty-two statements.

We described the four perspective groups starting with their strongest defining principle, subsequently the other principles follow an order to facilitate a narrative coming from their perspective, not necessarily reflecting the Q-sortation. When referring to a statement's Q-sortation, it is noted between parentheses. If a statement was negative, and for narration purpose a positive version of the statement was used, the Q-sortation outcome was changed into a positive as well. On top of that, some of the statements are not fully included to enhance the readability of the analysis.

Table 2
Interpretation overview, from score to RRI principle presence indicator.

Interpretation overview		
Score	Assigned meaning	Presence indicator
+5	Strongly agree	Strong
+4	Agree	Strong or moderate
+3	Agree	Moderate or strong
+2	Slightly agree	Moderate
+1	Not significantly agree	Contributing
0	Neutral	Contributing
−1	Not significantly disagree	Contributing
−2	Slightly disagree	Weak
−3	Disagree	Very weak or absent
−4	Disagree	Absent or very weak
−5	Strongly disagree	Absent

4.1. Group 1: the inclusiveness perspective

The study shows that this group believes being inclusive is very important in shaping the innovation process as well as the innovation itself to achieve societal desirable outcomes. Their perspective indicates that they view responsibility as a mutual inclusive concept this might be connected to their understanding that innovation and technology have the potential to change our morality. They do believe that quantum technology will change our values and there is need for a societal debate on its impact.

They strongly agree with the statement that an innovation approach for quantum technology needs to involve science, business, the government, and citizens (5). This group scores indicate that a dialogue between science, politics (policy), business and society should play a central role in innovation with quantum technology (4). They agree with the statement that a societal dialogue on quantum technology should create the process that results in the application of quantum technology (4). The agreement with these statements shows that they believe inclusiveness should lead to co-creation and co-production. This is emphasized by a statement from one of the respondents: "*It is necessary to include different viewpoints in an innovation approach, so you can clearly see what an innovation is supposed to do and what it means for the users.*"

This group strongly agrees with the statement that it is necessary to reflect on the possible outcomes of an innovation approach or innovation (5) and disagree that controversial subjects must be avoided in research and innovation with quantum technology (−4). They indicate that the national agenda for quantum technology should aim for societal goals (2). They disagree with the statement that science discovers, business applies, and society should adjust to the new possibilities (−5). This statement excludes actors when discovery is the sole domain of science or application is the sole domain of business. Their disagreement emphasizes the importance of inclusiveness in their perspective. It seems counter intuitive that this group remains neutral on adjusting existing policies to be responsive towards people that have a different view on an innovation (0), while they agree that perspectives from different stakeholders to make a judgement on the application of policies is necessary (5). This seems to point towards them believing everyone must have a chance to discuss their policies and put forward their interests without it leading towards a change in policies; they do not believe they should be responsive in a strong manner to an individual and be responsive towards everyone in an inclusive manner. It might be, that they try to integrate all the different views on their policies.

This group is neutral on government responsibility for addressing undesired outcomes of innovation (0) or being responsible for preparing society for innovation (0). They disagree with the statement that the process that results in the application of quantum technology should be created because of their policies or governmental policies (−3, −1). This suggests that this group is highly in favour of a mutual responsibility coming from the social dialogue.

This group is the only group that views new technology as a potential source of change for our morality and that technology is loaded with values. They disagree with the statement that technology is instrumental (−3), and they agree with the aspect that values and standards will change because of quantum technology (4) This is emphasized by one of the respondent's reactions: "*Technology is never simply instrumental. It carries a certain value and is not neutral. Once a door is opened, it cannot be closed!.*" As values may change society, this group strongly agrees with

Table 1
The scores for each group, every vertical row of scores belong to one group.

Score per perspective group				
Group:	1	2	3	4
1 An innovation approach for quantum technology needs to involve science, business, the government and citizens.	5	3	3	5
2 When innovating citizens, business and organizations without a clear stake in the innovation, may be ignored.	−4	−1	−3	−1
3 When persons without a clear stake in an innovation, reacts to that innovation, it is necessary to reflect on their reaction and to respond in an appropriate manner.	1	1	2	1
4 Perspectives from different stakeholders are not necessary to make a judgement on the application of policies.	−5	−4	−4	0
5 It is necessary to reflect on the possible outcomes of an innovation approach or innovation.	5	3	4	1
6 It is necessary to adjust existing policies to be responsive towards people that have a different view on an innovation.	0	−3	0	0
7 It is necessary to change policies and policy instruments to accommodate the introduction of quantum technology.	3	0	0	0
8 It is not important to understand technology or the innovation, it is all about the applications that emerge from them.	−3	3	−3	3
9 If a quantum technological application is not more sustainable then a conventional application, then it should not be used.	−2	−4	−1	−3
10 The national agenda for quantum technology is written by scientists and business, and as a cause of that not inclusive.	0	−3	−1	−1
11 The national agenda for quantum technology should aim for societal goals.	2	3	3	1
12 It is necessary to involve business with an approach for quantum technology.	2	5	2	4
13 It is necessary to involve science with an approach for quantum technology.	3	5	4	4
14 It is necessary to involve citizens with an approach for quantum technology.	3	0	1	0
15 Values and standards change because of quantum technology.	4	−2	−5	4
15 The Netherlands should keep her dominant position in the field of quantum technology.	1	4	1	3
17 Technology is instrumental, it is what humans do with specific applications that determines if the effect of it is desirable.	−3	4	4	5
18 The government is responsible for addressing undesired outcomes of innovation.	0	2	5	−4
19 It must be clear who is responsible for any effects coming from quantum technology before it may be applied.	−1	−1	3	2
20 Narratives about the future are a part of our reality, they are necessary to focus our thoughts on desirable innovations.	3	2	3	1
21 Creating narratives about the future are necessary to investigate if there are alternative technologies that would be considered better then quantum technology.	2	0	1	0
22 Science discovers, business applies and society should adjust to the new possibilities.	−5	1	−4	0
23 The government is responsible to prepare society for innovation.	0	1	1	−5
24 The process resulting in the application of quantum technology should be created through a societal dialogue on this technology.	4	−1	2	−2
25 The process resulting in the application of quantum technology should be created as a result of governmental policies.	−1	−3	0	−3
26 The process resulting in the application of quantum technology should be created by policies written by policy makers.	−3	−1	−2	−4
27 Controversial subjects must be avoided in research and innovation with quantum technology.	−4	−5	−2	−5
28 People do not have their values and standards readily available, and therefore these can't be taken up into the design of quantum technology.	−1	−3	−2	−2
29 The economic benefits are sufficient for large scale application of quantum technology.	−2	4	−3	−2
30 Quantum technology must be made available for lesser developed countries, the Dutch approach should provide this.	1	0	0	−4
31 An ethical discussion on quantum technology is useless if the United States and China will simply deploy it.	−4	−2	−5	−2
32 The Dutch approach takes sufficient account of preparing the central government for quantum technology.	−1	−1	−4	−1
33 The Dutch approach contains sufficient measures to steer the development of quantum technology from the central government.	−2	0	−2	−3
34 The Dutch approach must have frameworks and guidelines based on an Impact analysis of quantum technology.	2	2	2	1
35 It is right to Invest more in quantum technology than in other key technologies.	−3	1	−1	−1
36 The Dutch approach does not sufficiently lead to specific innovations to tackle challenges such as disease, crime, and social deprivation.	0	−2	−1	−1
37 It is necessary for the Dutch approach to quantum technology to do more in terms of scenario development.	0	1	0	3
38 The Dutch approach needs more diversity in age groups, cultural backgrounds, and different educational perspectives.	1	−2	0	2
39 Based on experience with other technologies, a layman can add more value to the Dutch approach than a specialist.	−2	−5	−1	2
40 A dialogue between science, politics (policy), business and society (citizens) should play a central role.	4	0	5	3
41 The Dutch approach in the field of quantum technology may, unasked, cause people to be provided with quantum technology	−1	2	−3	−3
42 Because quantum technology is difficult to understand, we need another way to understand its consequences in a cultural sense.	1	−4	1	2

Table 3
Analysis per perspective group based on the scores shown in table 1.

Analysis outcome per group	Group 1	Group 2	Group 3	Group 4
Anticipation	moderate	weak	moderate	moderate
Inclusiveness	strong	moderate	moderate	moderate
Reflexivity	strong	moderate	strong	weak
Responsiveness	weak	very weak	weak	weak
Co creation & Co production	strong	weak	strong	moderate
Sustainability	absent	absent	absent	absent
Technology destabilize morality	strong	absent	absent	absent

the idea of inclusiveness: everyone should have an opportunity to understand both the technology and the impact of the application of the technology. This idea is an underlying integral part of their perspective. They agree that it is necessary to change policies and policy instruments to accommodate the introduction of quantum technology (3) and that the Dutch approach must have frameworks and guidelines based on an impact analysis of quantum technology (2). This supports the presence of inclusiveness as policies, policy instruments, frameworks and guidelines give a structured approach to when an inclusive dialogue should take place. Sustainability is absent in the perspective of this group, this is shown by their slight disagreement with the statement; If a quantum technological application is not more sustainable then a conventional application, then it should not be used (−2).

Since inclusiveness is such a strong part of the perspective of this group, it might be that this group prioritizes the inclusive dialogue and the values from others above their own values. This opens the possibility

that this group ranked certain principles lower because of external influences, for example being a part of a mixed group of people that values economic growth above sustainability.

4.2. Group 2: the economic benefit perspective

The study shows that this group believes the pursuit of economic growth it the most important principle when addressing innovation with quantum technology. They indicate that dominance in the field of quantum technology is important and see participation as something that is conditionally necessary. The condition being the expected economic benefit.

The study outcome shows that the second group believes the economic benefits are sufficient to justify the large-scale application of quantum technology (4). They even agree with the idea that one may provide quantum technology without asking (2). They slightly agree on the view that science discovers, business applies, and society should adjust to the new possibilities (1). This is illustrated by a statement from one of the respondents: *"Business is the driving force!"*

They believe the Dutch are dominant in the field of quantum technology and it should remain so (4). All the findings above illustrate quite strongly that their perspective on quantum technology is driven by the expected economic advantage. They slightly agree with the statement that it is right to invest more in quantum technology than in other key technologies (1) as this would help in maintaining the Dutch dominance in the field of quantum technology.

They disagree that the process that results in the application of quantum technology should be created through a societal dialogue, policies written by policy makers, or governmental policies (−3, −1). This substantiates their believe that an economic market setting without governmental interventions is the best approach for this innovation. Hence it may be expected that their agreement with the idea of using a quadruple approach, the idea to involve science, business, the government, and citizens in quantum technological innovations (3), would be to boost the economic outcome and contribute to the Dutch domination in this field.

The study outcome shows a weak presence for anticipation. Maybe, they only want to anticipate aligning their efforts towards the best economic outcome. It is shown by their slight agreement with the statements: It is necessary for the Dutch approach to quantum technology to do more in terms of scenario development, the government is responsible to prepare society for innovation, the Dutch approach takes sufficient account of preparing the central government for quantum technology (1, 1, −1) and their strong disagreement with the statement: because quantum technology is difficult to understand, we need another way to understand its consequences in a cultural sense (−4)

Sustainability is not present in the perspective of this group. They strongly disagree with choosing technologies that are more sustainable (−4). It may be that this group pursues the most promising economic advancing technologies while not taking any other societal challenges in mind. This is supported by their disagreement with the statement: the Dutch approach needs more diversity in age groups, cultural backgrounds, and different educational perspectives (−4). This is further illustrated by a statement from one of the respondents: *"Many benefits can be imagined that do not necessarily enhance sustainability (in a direct way) but do have other societal benefits. Think of higher (economic) efficiency."*

The presence of reflexivity is moderate in this group's perspectives on quantum technology. This is shown by their agreement on the statement that it is necessary to reflect on the possible outcomes of an innovation approach or innovation (3). Reflexivity could be a way to judge whether the economic benefits of the technology meet expectations.

They agree with including business and science while they remain neutral on including citizens, this seems a moderate presence of inclusiveness and shown by their agreement with the statement: an innovation approach for quantum technology needs to involve science, business, the government, and citizens (3) and their neutral position on the statement that it is necessary to involve citizens with an approach for quantum technology (0). It substantiates their slight agreement on the statement that science discovers, business applies, and society adjusts to the new possibilities (1). The perspective suggests that this group prioritizes the economic benefits and the interests of business more than anything else.

4.3. Group 3: the responsibility perspective

The perspective of this group is unique in the way they sorted the statements concerning responsibility. They strongly agree with the idea that the government is responsible for addressing undesired outcomes of innovation (5) and they want clarity on who is responsible for any effects coming from quantum technology before it may be applied (3). This suggests that the core idea in the perspective of this group is: The Dutch government needs to take responsibility! This is emphasized by a statement from one of the respondents: *"Only the central government is in a position to take the right measures, which can prevent or combat the undesirable effects!"*

This group views technology as instrumental (4) and disagree that values and standards change because of the introduction of quantum technology (−5). This puts human action at the centre of what happens, the result of innovation with quantum technology as well as changing values and standards at large. As these are the result of human action responsibility can be appointed. This might be a contributing factor to their strong agreement with appointing responsibility. As this group thinks that they, as a part of the government, should take responsibility for an innovation approach and the outcome of innovation, it is logical to see that they want innovators to do more to prepare the central government for quantum technology. They disagree that the current innovation approaches take sufficient account of it (−4). This group has a need to understand the technology or innovation. This is shown by their disagreement with the statement that it is not important to understand technology or the innovation, it is all about the applications that emerge from them (−3). This need for understanding might be based on their view that there is a need for the government to play a strong role in the responsibility for addressing undesired outcomes.

The presence of anticipation is moderate, this is show by the agreement with the statement: narratives about the future are a part of our reality, they are necessary to focus our thoughts on desirable innovations (3) and their neutral position on the statement that it is necessary for the Dutch approach to quantum technology to do more in terms of scenario development (0). This could be the result of the idea that one must anticipate that which is deemed important when taking responsibility.

The study suggests this group is only responsive towards actors that have a specific responsibility. For example, an actor that is responsible for the subject of innovation, a field affected by the innovation or the innovation process. This is shown by their neutral position on the statements: it is necessary to adjust existing policies to be responsive towards people that have a different view on an innovation, and it is necessary to change policies and policy instruments to accommodate the introduction of quantum technology (0,0).

The principle that technology might destabilize morality, is not recognized by this group, as it is a contradiction to their believe that it is what humans do with technology that creates the outcome (4). According to them technology is irrelevant when it comes to change in organizations values. This is emphasized by a statement from one of the respondents: *"think that norms and values do not change that quickly and are fairly universal (in the western world). Quantum technology has no influence on that!."*

This group has no presence of sustainability in their perspective (−3), it may be a question of who takes responsibility or who appoints responsibility, and then it becomes an organizational issue that is hard to

address, as sustainability is a subject that should engage the entire organization.

4.4. Group 4: the inexorable outcome perspective

The core idea of this group seems to be that technology develops autonomously, and that society should adapt itself to new technology. As a result of this they do not believe that the government has a responsibility in preparing society for innovation (−5). This group does not see a proactive, contributing role for the government and would rather look at the developing quantum technology trying to perceive the outcome. They view innovation as something inevitable, that the outcome of innovation will be, no matter what they do themselves. This is substantiated by their disagreement with governmental responsibility for addressing undesired outcomes of innovation and their strong disagreement with the idea that the government is responsible to prepare society for innovation (−4). This group does not agree with the creation of the process that results in the application of quantum technology through a social dialogue, based on governmental policies or by policies written by policy makers (−3, −4, −5).

This group is the only group that agrees to invest more in understanding the impact of quantum technology via scenario development (3). They agree with the idea that quantum technology is hard to understand and there is a need for another way to understand the cultural consequences (2), while they disagree that the Dutch approach contains sufficient measures to steer the development of quantum technology from the central government (−3). This substantiates their believe: Innovation will be, and the outcome may be perceived, so it is necessary to arrange as much measures as possible to steer the development. While at the same time believing that it will not change the outcome of the innovation on a grander scale. They do want to know what the outcome may be, this suggest that they do want to prepare for the outcome. Like a person that prepares for a disaster by stocking up on food and water.

This group conceives of technology as instrumental, it is what humans do with quantum technology that will dictate the outcome (5), while they also believe that values and standards will change because of quantum technology (4). This suggests that they believe it is inevitable what humans will do with the technology and they do not have any influence on what humans will do. That might explain why they strongly disagree that quantum technology must be made available for lesser developed countries (−4). It suggests that this group does not have a lot of faith in humanity.

This group has an indifference towards the view on innovation and the inclusion of citizens (0), they have a slight agreement to reflect on the possible outcomes of innovation with quantum technology (1). It may be that this reflection is acknowledging the effect it has instead of the innovation itself, not to adjust future innovation approaches, just to appoint what little responsibility there is. This is emphasized by their agreement that it must be clear who is responsible for any effects coming from innovation with quantum technology (2). This group agrees that a dialogue between science, politics (policy), business and society (citizens) should play a central role (3), it may be that they want to know who will be affected by the outcome. As they might believe it is inevitable, this is partly shown by their agreement; that based on experience with other technologies, a layman can add more value to the Dutch approach than a specialist (2).

The presence of anticipation is moderate, they might believe that it is necessary to anticipate an innovation to know the outcome and at the same time they do not want to perceive the negative effects, because they believe it is inevitable. This is shown by their slight agreement and agreement with the statements; Narratives about the future are a part of our reality, they are necessary to focus our thoughts on desirable innovations (1), it is necessary for the Dutch approach to quantum technology to do more in terms of scenario development (3). This is emphasized by a statement from one of the respondents: *"Technology is not always something we can control. We can make judgements about what we do with a technology, but in some cases a technology can change our view of the world around us, so that desirable behaviour can become undesirable behaviour and* vice versa.*."*

The presence of inclusiveness is moderate, this show by their agreement with the statement that an innovation approach for quantum technology needs to involve science, business, the government and citizens (5) and their neutral position on the statements that perspectives from different stakeholders are not necessary to make a judgement on the application of policies (0) and it is necessary to involve citizens with an approach for quantum technology (0) it suggests that they believe it is not necessary to include everyone in the creation of the innovation process, as this is ineffective in changing the outcome, and they might believe inclusiveness is necessary to reflect upon the outcome, more in a perceiving manner then an active manner to mitigate any unwelcome effects. The presence of reflexivity is weak, this is shown by their slight agreement with the statements; it is necessary to reflect on the possible outcomes of an innovation approach or innovation (1), when persons without a clear stake in an innovation, reacts to that innovation, it is necessary to reflect on their reaction and to respond in an appropriate manner (1)

Responsiveness is absent in the perspective of this group, this might suggest that they do not see a need for being responsive, as changing their policies would not change the inevitable outcome. This is shown by their neutral position on the statements; It is necessary to adjust existing policies to be responsive towards people that have a different view on an innovation (0), it is necessary to change policies and policy instruments to accommodate the introduction of quantum technology (0). This might be the same reason for taking up co-creation or co-production in moderation into their perspective (−2, 3). As the outcome of innovation does not change in their perspective, they might as well participate in the innovation on a co-creation or co-production basis to better understand the benefits.

The principle that technology might destabilize our morality (norms and values) is not taken up into the perspective of this group, they strongly believe that: What humans do with an innovation is what creates the outcome (5). This would suggest that this group sees innovation not as a technological wave, they rather see it as a means and an outcome of human acting, and it might suggest this group does not have much faith in the capability of humanity to steer innovation towards desirable outcomes and away from undesirable outcomes.

Sustainability is absent in the perspective of this group (−3), as they believe a technology or innovation is what it is, and it is sustainable or not, and the fact that it is or is not sustainable is ineffective in preventing humanity to introduce it into our world.

5. Conclusion & discussion

We extracted seven principles of RRI that are shared amongst the different academic views on RRI to enable us to assess if RRI is part of the shared perspectives of Dutch policy officers. These principles are anticipation, inclusiveness, reflexivity, responsiveness, co-creation & co-production, sustainability, and the understanding that new technology destabilizes our morality.

With a Q-method study, using multiple statements, we found four Dutch policy officers' shared perspectives that show to what extent RRI principles are part of them.

The data from the study shows that:

- *Anticipation* is moderately present in three groups and weakly present in one group.
- *Inclusiveness* is moderately present in three groups and strongly present in one group.
- *Reflexivity* is strongly present in two groups, moderately in one group and weakly present in one group.
- *Responsiveness* is present weakly in three groups and very weakly in one group.

- *Co creation & Co production* is strongly present in two groups, moderately in one group and weakly present in one group.
- *Sustainability* is absent in all groups.
- The principle that *new technology destabilizes our morality* is absent in three groups and strongly present in one group.

Moreover, this study unearthed three perspectives that might not be addressed sufficiently within the current RRI narrative: The pursuit of economic growth, the need to assign responsibility and the believe in an explorable outcome. These must be considered when endeavouring to embed or apply RRI to address societal challenges of our time. Follow-up questions of interest are: Do these perspectives unearth other principles that play a significant role in governmental policies? What do these other principles contribute to aligning research and innovation to the values, needs and expectations of society, to address contemporary societal challenges?

As policies in the Netherlands are prepared, written, and adjusted by Dutch policy officers based on their perspectives which lack some RRI principles or have them weakly present, this study casts doubts on whether RRI is considered when creating or adjusting governmental policies on science and technology and consequently on the effectiveness of the European Union's endeavour to make it part of the governmental policies on science and technology. The weak presence of RRI principles in the perspectives of Dutch policy officers could be averse to the goals that are pursued with quantum technology. The Dutch National Agenda Quantum Technology states high level goals for quantum technological innovations, these are: international ground-breaking research, economic benefits for the Netherlands, pioneering in regulations and ethics, ground-breaking applications, and solutions for societal challenges (Nationale agenda quantum technologie, September 2019). The result of this study suggests that Dutch policy officers may sustain or implement policies that might complicate reaching those goals. For example, sustainability is widely seen as a societal challenge. Yet researchers aiming at an innovation approach with quantum technology addressing that specific challenge, will find that some of the Dutch policy officers do not have sustainability as a part of their shared perspective on innovation with quantum technology and are not likely to change policies to facilitate that approach. If an innovation approach is looking for a societal dialogue, some of the Dutch policy officers would partake, while they are not likely to change policies, even when important issues would be raised, this because the presence of responsiveness is weak to very weak.

Further this study suggests that the Dutch government may not be responsive to- or understand the cultural impact of innovation with quantum technology, as responsiveness is present in a very weak or weak manner and the understanding that technology destabilizes our morality lacks in three of the four shared perspectives of its Dutch policy officers. As a result, one may expect the Dutch government may only try to intervene in hindsight, when a negative societal outcome is manifest, and the cultural impact of innovation with quantum technology has come and gone.

We would like to emphasize that this study took place in the Netherlands, and Dutch cultural anchors may be a contribution factor towards the outcome. Furthermore, this study was dependent on the respondents cognitive understanding of the vocabulary used, given the position and level of the respondents within the Dutch governmental organisations, we are confident that this cognitive understanding was sufficient for this study. In a dialogue with the Dutch policy officers, behaviour may be different than we projected in the conclusions, as multiple other factors could come into play, like hierarchical relations, cultural influences, and contemporary circumstances.

Finally, one may wonder, what additional efforts can be envisaged to change Dutch policy offers perspectives to increase and fortify the presence of RRI principles. This study shows that the current European Unions' efforts are not effective in creating a significance presence of RRI principles in the shared perspectives of Dutch policy officers. It may give means to arrive at additional efforts from the European Union and the Dutch government, fortifying RRI principles in the perspectives of Dutch policy officers by offering more information, instruction, and guidance in a uniform way, however that may not work, as this study also revealed that the policy offers have shared perspectives that suggest other principles are at play. This may need more tailormade efforts to fortify RRI principles, for example: courses, training programs or workshops based on the current perspectives of the Dutch policy officers, confronting the Dutch policy officers with their perspectives, and addressing the way RRI and the RRI principles could contribute to specific governmental and societal goals.

Data availability statement

All anonymised or aggregated data, and/or all other non-personal data will be available at 4TU.ResearchData with public access.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

The authors would like to acknowledge all the Dutch policy officers, ministries and agencies that participated in the study.

The authors would like to acknowledge Professor Dr Rene von Schomberg for contributing information on the European Horizon Programs.

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