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Co-shaping the Future in Quadruple Helix Innovation Systems: Uncovering Public Preferences toward Participatory Research and Innovation

Abstract The Quadruple Helix Model of innovation recognizes four major actors in the innovation system: science, policy, industry, and society. In keeping with this model, more and more governments are prioritizing greater public involvement in innovation processes. The goal of this study was to identify desirable and productive forms of interaction between the scientific community and the public. Our analysis focuses on the point of view of societal actors, which has so far been largely neglected in scientific literature and political discourse. To this end, we interviewed 50 laypersons with participatory research and innovation experience in Germany to document their opinions of the value of such interaction, the goals it should pursue, and the forms it should take. Rather than preferring the democratization of science in general, interviewees expressed the desire for more extensive opportunities to introduce scientific and technological considerations as part of bidirectional exchanges between academia and society. This paper proposes a layperson typology intended to help design participatory processes that facilitate such exchanges and includes the differences in opinions between men and women.

Keywords
Participation in research and innovation
Early stakeholder involvement
Quadruple Helix

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Civil Society as Major Actor in National Innovation Systems

Collaborative Innovation following the Quadruple Helix Model

Until the 1990s, the basic premise underpinning most national innovation systems was that scientific findings and inventions would naturally lead to economic development and therefore societal advancement. The R&D community drove research trajectories in basic, applied, and industrial research, and members of the public played the part of passive innovation recipients. A new approach has gained in prominence over the last two decades, however. Research trajectories must be legitimized among relevant publics, aim at positive public impact,[1] and be defined with the public's help.[2] The expectation is that involving societal stakeholders and individual laypersons will help to re-align research trajectories with public preferences and lead to more welcome, sustainable, solutions.[3]

The Quadruple Helix model was originally conceptualized by Elias Carayannis and David Campbell as a spiral with four strands.[4] Our adaptation (Figure 1) looks at the helix from above. It clearly demonstrates that the four core components of an innovation system – academia, industry, government, and society – are not involved in unidirectional push-pull relationships, but rather in multi-layered, dynamic, bi-directional interactions. This highlights the role of society as a major actor in national innovation systems as well as the importance of actively integrating the public into innovation projects.

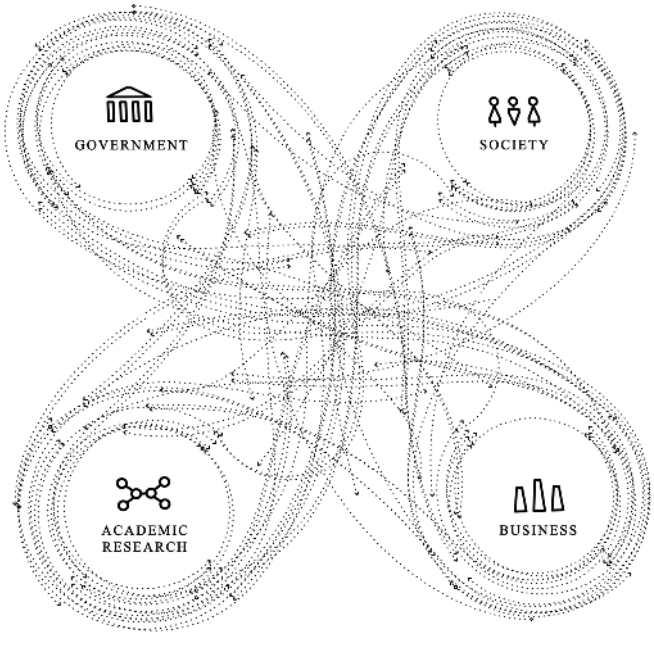

Figure 1 The Quadruple Helix Model adapted by Fraunhofer (2016), originally developed by Carayannis and Campbell (2009). Copyright © 2015 Fraunhofer.

Involving Members of Society: Necessary, but Challenging

Today, involving the public in research, development, and innovation is the dominant paradigm both in international STI-policy and in innovation research. The concept forms the backbone of several national innovation policies, strengthening regional innovation systems and enabling better evaluation of research organizations and research proposals.[5] Collaborating with societal actors not only meets an established standard – cooperation and collaboration is the duty of every actor in an innovation system.

There are two major challenges to incorporating laypersons into the innovation process. Firstly, there is a methodological challenge: how can individuals effectively introduce their (public) perspective? And how can actors from academia, business, and government benefit from society's knowledge? Second, there is the problem of defining the functional role of society as the fourth actor in

1 Lutz Bornmann, "What Is Societal Impact of Research and How Can It Be Assessed? A Literature Survey," *Journal of the American Society for Information Science and Technology* 64, no. 2 (2013): 217–33, DOI: https://doi.org/10.1002/asi.22803; Ben R. Martin, "The Research Excellence Framework and the 'Impact Agenda': Are We Creating a Frankenstein Monster?," *Research Evaluation* 20, no. 3 (2011): 247–54, DOI: https://doi.org/10.3152/095820211X13118583635693.

2 Frank W. Geels and Johan Schot, "Typology of Sociotechnical Transition Pathways," *Research Policy* 36, no. 3 (2007): 399–417, DOI: https://doi.org/10.1016/j.respol.2007.01.003; Michael Søgaard Jørgensen et al., "The Social Shaping Approach to Technology Foresight," *Futures* 41, no. 2 (2009): 80–86, DOI: https://doi.org/10.1016/j.futures.2008.07.038; Elias G. Carayannis and David F.J. Campbell, "'Mode 3' and 'Quadruple Helix': Toward a 21st Century Fractal Innovation Ecosystem," *International Journal*

collaborative innovation processes: why should laypersons be involved and what should they contribute? What goals might societal actors pursue during their participation?

To fruitfully implement quadruple helix innovation processes, the specific forms such interactions might take are yet to be determined.[6] Academia, government and business – the other three of the four subsystems of the quadruple helix – have already framed collaboration with society as *transdisciplinarity*, *open science* and *deliberate democracy*, and *user-centered innovation* respectively. But these discourses only take place at an academic level or within the individual subsystems, while there have been "remarkably few attempts … to engage the public in dialogue about the sorts of arrangements they would prefer science to be governed by."[7] In particular, there is a research gap with regard to the aims and motives of the public as a new and relevant contributor to innovation initiatives. We must gain a clearer understanding of these to foster the quadruple helix innovations that STI policies and innovation research demands.[8]

This article focuses on that neglected dialogue with members of society about their relatively new role in innovation processes. First, we will present the perspectives of science, government, and industry regarding collaboration with society. After that, our presentation of a research project called *Shaping Future* will illustrate the current methodological challenges of innovation processes involving society. Finally, to close the research gap, we supply empirical data to show the motives and goals societal actors have for participating in quadruple helix innovation processes. From these findings we derive recommendations for the design of participatory research and innovation formats.

Society as Actor in Research and Innovation: Current Perspectives

Academia: Transdisciplinarity

Because greater public involvement entails greater demand for inter- and transdisciplinary processes, the scientific community is facing increasing pressure to elaborate and refine existing understandings of knowledge and the methods of its production and transfer. What is known as *mode 1* is a conventional method of generating knowledge; by focusing on knowledge production within academia, it leads to mono-disciplinary, homogeneous, primarily cognitive information, and organizationally hierarchical knowledge. The knowledge resulting from processes classified as *mode 2*[9] or 3[10] is transdisciplinary, heterogeneous, and transient – it always emerges from interactions among diverse actors, and is therefore socially and economically applicable rather than universal.[11]

The term mode 3 was introduced by Carayannis and Campbell.[12] It extends the model known as mode 2, which was coined by Michael Gibbons and his colleagues in 1994.[13] Mode 3 entails different transdisciplinary processes taking place simultaneously, creating "hybrid synergies and additionalities,"[14] while individual knowledge bases and paradigms of innovation continue to co-evolve within modern, glocal innovations systems.

At the same time, number of publications and journal rankings remain the most common measures of academic performance, which makes assessing the social impact of mode 3 processes extremely difficult.[15] This difficulty can lead to resistance toward participation of societal actors in research and innovation[16] and thus ultimately impede the pursuit of transdisciplinarity.

Government: Open Science and Democracy

In Europe, the term "major social challenges" features heavily in white papers, grant announcements, and offers for public funding in high-priority fields, all of

of Technology Management 46, no. 3/4 (2009): 201–34, DOI: https://doi.org/10.1504/IJTM.2009.023374; Elias G. Carayannis and David F.J. Campbell, *Mode 3 Knowledge Production in Quadruple Helix Innovation Systems* (New York: Springer, 2012); Jack Stilgoe et al., "Why Should We Promote Public Engagement with Science?," *Public Understanding of Science* 23, no. 1 (2014): 4–15, DOI: https://doi.org/10.1177%2F0963662513518154; Richard Owen et al., "Responsible Research and Innovation: From Science in Society to Science for Society, with Society," *Science and Public Policy* 39, no. 6 (2012): 751–60, DOI: https://doi.org/10.1093/scipol/scs093.

3 Eric von Hippel, *The Sources of Innovation* (New York: Oxford University Press, 1988); Henry William Chesbrough, *Open Innovation: The New Imperative for Creating and Profiting from Technology* (Boston: Harvard Business Review Press, 2003); Martina Schraudner and Solveig Wehking, "Fraunhofer's Discover Markets: Fostering Technology Transfer by Integrating the Layperson's Perspective," in *Technology Transfer in a Global Economy*, ed. David B. Audretsch et al. (New York: Springer, 2012), 367–74; Han Woo Park, "Transition from the Triple Helix to N-Tuple Helices? An Interview with Elias G. Carayannis and David F. J. Campbell," *Scientometrics* 99, no. 1 (2014): 203–7, DOI: https://doi.org/10.1007/s11192-013-1124-3.

4 Carayannis and Campbell, "'Mode 3' and 'Quadruple Helix,'" 207; Carayannis and Campbell, *Mode 3 Knowledge Production*.

5 Simona Cavallini et al., *Using the Quadruple Helix Approach to Accelerate the Transfer of Research and Innovation Results to Regional Growth* (Brussels: European Union, 2016), DOI: https://doi.org/10.2863/408040; Maura McAdam and Koenraad Debackere, "Beyond 'Triple Helix' toward 'Quadruple Helix' Models in Regional Innovation Systems: Implications for Theory and Practice," *R&D Management* 48, no. 1 (2018): 3–6, DOI: https://doi.org/10.1111/radm.12309.

6 Kristel Miller et al., "Knowledge Transfer in University Quadruple Helix Ecosystems: An Absorptive Capacity Perspective," *R&D Management* 46, no. 2 (2016): 383–99, DOI: https://doi.org/10.1111/radm.12182.

which often mention or require public involvement.[17] One such issue is climate change. For roughly two decades, policymakers have been debating how the challenge(s) of mitigating climate issues might be resolved with the help of participatory projects and research policies.[18] These debates have given rise to a shared recognition that the way the scientific community and the public interact must be redefined. A number of differing, sometimes controversial positions on the matter of participatory research have emerged. Other related matters, such as transdisciplinarity, mode 2 knowledge production, sustainable innovation, and social transformation are the terrain of wider discussions about the value of including the public in research efforts.[19]

Greater public involvement in research and innovation can serve to legitimize research trajectories and produce more welcome, sustainable innovations by re-orienting research and development toward public preferences. In new and emerging fields of science and technology, including the public may provide access to more diverse, directly applicable knowledge.[20] In fact, large-scale funding programs[21] are increasingly evaluating proposed projects on how closely they will involve potential users and other relevant individuals and on how much space and weight their considerations will be given.

Finally, participatory and democratic processes are needed to boost political and scientific legitimacy among the citizenry, particularly in cases involving complexity and technological uncertainty, and whenever the public will be greatly impacted.[22] "Open science" efforts, for example, are deliberately democratic:[23] citizens are granted unlimited access to research and documentation for, or even direct influence over, innovation processes and results. Open science implies a broader communication of scientific findings and the collaborative development of digital solutions or academic performance measures among professionals and laypersons.

Politically speaking, greater public involvement seems therefore (1) necessary, because it can help resolve major challenges; (2) practical, because it can help produce more welcome innovations; and (3) ethically just, because the taxpayer, as primary funder, can gain greater access to and influence over the innovation process and its results.

Business/Industry: User-Centeredness

Businesses often organize participatory projects to gauge their products' market value. These projects draw from concepts such as *lead user*,[24] *open innovation*,[25] and *user innovation*[26] in which lay input is regarded as the engine of innovation[27] and the foundation for demand-oriented innovation policies.[28] These projects, however, have comparatively narrow foci: for participants to assess specific, practically final products for which these participants represent specific, comparatively narrow groups of potential users.

Members of the Public: To Be Determined

Within a cross-European survey commissioned by the Directorate-General for Communication in 2014,[29] at least half of the people surveyed in most countries expressed interest in science and technology. Perhaps unsurprisingly, this interest positively correlated with the belief that one is well informed about current developments in science and technology. In Germany in 2014 and 2015, the proportions of those surveyed by Wissenschaftsbarometer who wished to co-determine research trajectories constituted 33 and 34 percent respectively. In 2016, this proportion increased to 40 percent, while only 23 percent asserted that the public was sufficiently involved in such decisions.[30] In Switzerland in 2016, 36 percent of those surveyed stated that they wished to participate in research projects.[31]

7 Patrick Sturgis, "On the Limits of Public Engagement for the Governance of Emerging Technologies," *Public Understanding of Science* 23, no. 1 (2014): 40, DOI: https://doi.org/10.1177%2F0963662512468657.

8 Kristel Miller et al., "A Systematic Literature Review of University Technology Transfer from a Quadruple Helix Perspective: Toward a Research Agenda," *R&D Management* 48, no. 1 (2018): 7–24, DOI: https://doi.org/10.1111/radm.12228.

9 Michael Gibbons et al., *The New Production of Knowledge: The Dynamics of Science and Research in Contemporary Societies* (Thousand Oaks: Sage Publications, 1994).

10 Carayannis and Campbell, *Mode 3 Knowledge Production*.

11 Gibbons et al., *New Production of Knowledge*.

12 Carayannis and Campbell, *Mode 3 Knowledge Production*.

13 Gibbons et al., *New Production of Knowledge*.

14 Carayannis and Campbell, "'Mode 3' and 'Quadruple Helix,'" 206.

15 Martin, "The Research Excellence Framework"; Trisha Greenhalgh et al., "Research Impact: A Narrative Review," *BMC Medicine* 14, no. 1 (2016): Art. 78, DOI: https://doi.org/10.1186/s12916-016-0620-8; Bornmann, "Societal Impact of Research," 217–33; Teresa Penfield et al., "Assessment, Evaluations, and Definitions of Research Impact: A Review," *Research Evaluation* 23, no. 1 (2014): 21–32, DOI: https://doi.org/10.1093/reseval/rvt021; Andrew J. Milat et al., "A Narrative Review of Research Impact Assessment Models and Methods," *Health Research Policy and Systems* 13, no. 1 (2015): 18, DOI: https://doi.org/10.1186/s12961-015-0003-1.

16 Wissenschaftsrat, *Wissens- und Technologietransfer als Gegenstand institutioneller Strategien: Positionspapier* (Weimar: Wissenschaftsrat, 2016), 1–52, available at https://www.wissenschaftsrat.de/download/archiv/5665-16.pdf; Anna Sinell et al., "Uncovering Transfer—A Cross-National Comparative Analysis," *European Journal of Innovation Management* 21, no. 1 (2017): 70–95, DOI: https://doi.org/10.1108/EJIM-01-2017-0006.

Thus far, laypersons have been invited to express their opinions or co-develop ideas within specific research projects, typically either on a volunteer basis or in exchange for small financial compensation. Two rare examinations of laypersons' motivations for becoming involved were conducted as part of two citizen science projects: one that crowdsourced transportation schedule improvements[32] and the other in which laypersons helped categorize galaxies.[33] Their motivations were found to be very diverse, including the desire to learn, advance one's career, and achieve recognition as well as to belong, share a quality experience, and co-produce. Within the former study, the project website being perceived as well-designed and visitor-friendly was also stated to be a factor. At the same time, the frequency with which any particular motivation was mentioned was not measured in either study.

Such studies can shed light on public preferences toward their own involvement. However, they remain scarce. At the same time, both the scientific community and practitioners will likely find the information about "what works best when" extremely useful.[34]

Societal Involvement and New Approaches to Participation

Transdisciplinarity as Challenge

One major challenge that plagues public participation in tech innovation is known as the *Collingridge dilemma*: the full functionality and impact of a technology cannot be easily predicted until it is sufficiently developed and widely used, after which time it is difficult to make any substantial changes.[35] Moreover, while technology assessment requires expertise, technology itself is characterized by ambivalence, complexity, and uncertainty.[36]

These factors suggest that the potential ramifications inherent in introducing new technologies are extremely difficult even for experts such as engineers and decision-makers to predict, let alone laypersons and public stakeholders. Involving those from the latter group, who have little to no familiarity or interest with regard to technology, comes with its own set of challenges. Too many motivations and interests may become a barrier to communication, lead to unbalanced power dynamics, and obstruct the flow of interaction among individuals from diverse backgrounds. Finally, existing participatory methods typically rely on verbal expression and conventional thought patterns, which may limit possible ways of envisioning desirable futures.[37]

The goal of this empirical study was to identify approaches that can help not only resolve these challenges, but best support – particularly from the layperson's perspective – the interactions among Quadruple Helix actors. The study was conducted as part of a research project called *Shaping Future*, which we will describe in the following section in more detail.

Shaping Future: Interdisciplinary Methods to Support Transdisciplinarity

Shaping Future pursued the development of new, interdisciplinary methods of public participation to help integrate public preferences into research agendas and technology development. Funded by the German Ministry of Education and Research, the project complied with both current national and European research policies increasingly attributing significance to participation.[38]

Scientifically proven approaches, methods, and tools from participatory design provided the methodological basis for our project.[39] A key feature of participatory design projects is that they qualify laypersons as experts in experience and preference and integrate them early on in the design process. For our research project, we applied this approach in the context of research planning. Our goal was to

17 European Commission, *Horizon 2020—The Framework Programme for Research and Innovation* (Brussels: European Union, 2011), 1–14, accessed April 28, 2019, http://ec.europa.eu/research/horizon2020/pdf/proposals/com(2011)_808_final.pdf; Wissenschaftsrat, *Zum wissenschafts-politischen Diskurs über Große gesellschaftliche Herausforderungen: Positionspapier* (Weimar: Wissenschaftsrat, 2015), accessed April 28, 2019, https://www.wissenschaftsrat.de/download/archiv/4594-15.pdf.

18 Wissenschaftlicher Beirat Globale Umweltveränderungen, *Welt im Wandel: Gesellschaftsvertrag für eine Große Transformation* (Berlin: WBGU Berlin, 2011), accessed May 3, 2019, https://www.bundestag.de/resource/blob/434158/.../adrs-18-228-data.pdf; James Ivan Scrase et al., *Transformative Innovation: A Report to the Department for Environment, Food and Rural Affairs* (Brighton: University of Sussex, 2009), DOI: https://doi.org/10.13140/2.1.4629.5849.

19 Uwe Schneidewind and Mandy Singer-Brodowski, *Transformative Wissenschaft: Klimawandel im deutschen Wissenschafts und Hochschulsystem* (Marburg: Metropolis-Verlag, 2014); Peter Strohschneider, "Zur Politik der Transformativen Wissenschaft," in *Die Verfassung des Politischen: Festschrift für Hans Vorländer*, ed. André Brodocz et al. (Wiesbaden: Springer Fachmedien Wiesbaden, 2014), 175–92; Armin Grunwald, "Transformative Wissenschaft—eine neue Ordnung im Wissenschaftsbetrieb?," *GAIA – Ecological Perspectives for Science and Society* 24, no. 1 (2015): 17–20, DOI: https://doi.org/10.14512/gaia.24.1.5; Uwe Schneidewind and Carsten von Wissel, "Transformative Wissenschaft: Warum Wissenschaft neue Formen der Demokratisierung braucht," *Forum Wissenschaft* 32, no. 4 (2014): 4–8, available at https://epub.wupperinst.org/files/6123/6123_Schneidewind.pdf.

20 Jakob Edler and Luke Georghiou, "Public Procurement and Innovation: Resurrecting the Demand Side," *Research Policy* 36, no. 7 (2007): 949–63, DOI: https://doi.org/10.1016/j.respol.2007.03.003. Geels and Schot, "Typology," 399–417; Denis Loveridge and Ozcan

develop an interdisciplinary methodology to integrate laypersons into what has been primarily an expert-driven process.

People, in the capacity of experts, within specific application contexts, provide particularly solid points of departure for these participatory design processes. The goals of a participatory approach to agenda setting in *Shaping Future* are to collaboratively explore social realities,[40] to develop alternative approaches to technology development, and, ultimately, to create socially robust technological solutions.[41]

As opposed to language-based methods from the social sciences and futures studies, methods developed in *Shaping Future* engage multiple senses, promote interaction on multiple levels, and encourage experimentation. They equip laypersons to fulfill their new, more fundamental role of utilizing their experiences to enhance the entire technology development process.[42] They allow laypersons' interactions to transcend the limitations of purely verbal formulations and pre-existing schemas of knowledge, which promotes unconventional solutions and original visions of the future.[43]

During a series of co-ideation workshops, we utilized several methods to enable laypersons – people from a broad variety of social and professional backgrounds who participated in the project as non-professionals – to explore their preferences for future human-machine interaction in the workplace, relationships, healthcare, and transportation. One such method was *participatory prototyping*: the laypeople created narrative objects by using basic materials in unconventional ways (Figure 2). They were not intended to be elaborate mock-ups of specific technological products. The prototypes' purpose was rather to inspire novel directions that technological advances might take and elicit shared reflections around these directions. By giving participants from diverse backgrounds the opportunity to articulate their needs and wishes, our method enabled them to transcend everyday practicality and professional terminology in order to effectively interact.

Over the course of the project, we organized four workshops with a total of 78 participants and one exhibition with a total of 3,000 visitors. Workshop participants included men and women in roughly equal proportions with the broadest ranges of ages and backgrounds possible. The goal was to access the greatest variety of lay input available rather than to gather a representative sample. While some participants did, in fact, come from research or technology fields, these fields were sufficiently unrelated to the subject matter for them to contribute exclusively in a non-professional capacity. Another goal was to establish a physical space where highly diverse participants could share their reflections face to face, as opposed to them doing so online. This approach helped utilize complementary knowledge and foster creativity in solution development.[44]

In its overall variety, the data gathered – physical artifacts, written descriptions, audio, and video recordings – indirectly manifested participants' preferences

Saritas, "Reducing the Democratic Deficit in Institutional Foresight Programmes: A Case for Critical Systems Thinking in Nanotechnology," *Technological Forecasting & Social Change* 76, no. 9 (2009): 1208–21, DOI: https://doi.org/10.1016/j.techfore.2009.07.013; Jørgensen et al., "The Social Shaping Approach."

21 European Commission, *Horizon 2020*, 1–14; Directorate-General for Research and Innovation (European Commission), *Europe's Ability to Respond to Societal Challenges* (Brussels: European Union, 2012), accessed May 3, 2019, https://publications.europa.eu/en/publication-detail/-/publication/bb29bbce-34b9-4da3-b67d-c9f717ce7c58; Directorate-General for Communication (European Commission) and Directorate-General for Research and Innovation, *Responsible Research and Innovation (RRI): Science and Technology* (Brussels: European Union, 2013), accessed May 3, 2019, https://publications.europa.eu/en/publication-detail/-/publication/ee9bacdf-fdad-46eb-8cd8-32879e310191/language-en.

22 Daren C. Brabham, "Motivations for Participation in a Crowdsourcing Application to Improve Public Engagement in Transit Planning," *Journal of Applied Communication Research* 40, no. 3 (2012): 307–28, DOI: https://doi.org/10.1080/00909882.2012.693940; Seyla Benhabib, ed., *Democracy and Difference: Contesting the Boundaries of the Political* (1996; Princeton: Princeton University Press, 2008); Eva Lövbrand et al., "A Democracy Paradox in Studies of Science and Technology," *Science, Technology & Human Values* 36, no. 4 (2010): 474–96, DOI: https://doi.org/10.1177%2F0162243910366154; Amy Gutmann and Dennis F. Thompson, *Why Deliberative Democracy?* (Princeton: Princeton

Figure 2 *Shaping Future* methods. Copyright © 2016 Fraunhofer.

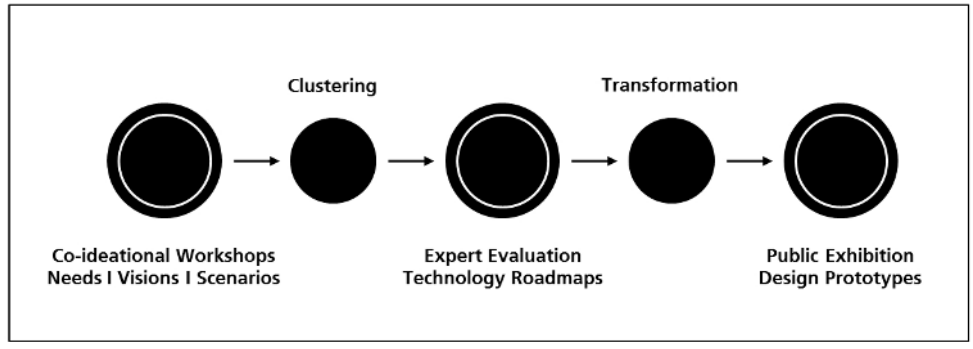

Figure 3 *Shaping Future*: the process. Copyright © 2016 Fraunhofer.

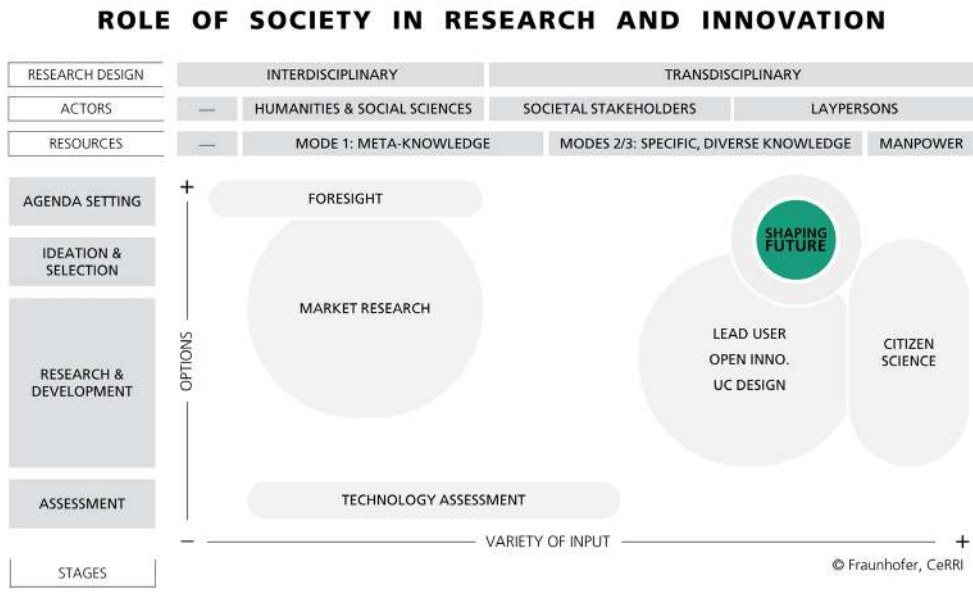

Figure 4 *Shaping Future* within the wider landscape of participatory research and innovation. Copyright © 2018 Fraunhofer.

for human-machine interaction. To extrapolate these preferences and make them understandable and useful to participating specialists, we needed to develop a methodologically sound approach. We adapted the explicative content analysis method[45] to develop a procedure for data analysis that was systematic, incorporated methodological principles, and followed clearly defined rules. As opposed to generating a purely subjective interpretation of the data, this procedure is inter-subjectively verifiable – can be comprehended, followed, and validated by others, and thus meets the standards for a scientific method, particularly within the social sciences.[46]

With the help of this procedure, we analyzed the aggregate data and extracted participants' preferences for human-machine interaction. During a follow-up professional evaluation workshop, 14 Fraunhofer (research organization) specialists from 10 different professional fields were presented with the refined data, including the artifacts, and mapped out the steps towards implementing the laypersons' ideas on technology development roadmaps.

The results of *Shaping Future* included an original, three-stage model of research and innovation process (see Figure 3) as well as a range of original methods to employ at each stage (see Figure 2). These stages are (1) a series of workshops in which laypersons produce ideas and objects intended to express their preferences toward technological advances, followed by clustering of their ideas; (2) an expert assessment phase in which engineers estimate when proposed developments may become possible and project these onto technology roadmaps; and (3) before transforming the objects into design prototypes, a public display of the prototypes

University Press, 2004); Loren A. King, "Deliberation, Legitimacy, and Multilateral Democracy," *Governance* 16, no. 1 (2003): 23–50, DOI: https://doi.org/10.1111/1468-0491.t01-1-00203; Sabine Maasen and Peter Weingart, eds., *Democratization of Expertise? Exploring Novel Forms of Scientific Advice in Political Decision-Making* (Dordrecht: Springer, 2009); Jørgensen et al., "The Social Shaping Approach"; Michael Gibbons, "Science's New Social Contract with Society," *Nature* 402 (1999): C81–C84, DOI: https://doi.org/10.1038/35011576.

23 Mark Elam and Margareta Bertilsson, "Consuming, Engaging and Confronting Science," *European Journal of Social Theory* 6, no. 2 (2003): 233–51, DOI: https://doi.org/10.1177%2F1368431003006002005; Benedikt Fecher and Sascha Friesike, "Open Science: One Term, Five Schools of Thought," in *Opening Science: The Evolving Guide on How the Internet Is Changing Research, Collaboration and Scholarly Publishing*, ed. Sönke

intended to encourage shared reflection on new and emerging areas of research and technology.

The graph in Figure 4 illustrates where *Shaping Future* fits within the grand scheme of participatory approaches. The x-axis displays a continuum ranging from narrowest to broadest in terms of diversity of participants, the number of fields of study involved, and the methods of knowledge production. The y-axis shows different stages in research and development ranging from agenda setting to the assessment of an innovation's impact. The higher on each axis an event can be placed, the greater the diversity of input and participants' opportunity to co-determine research trajectories.

Methodology: Defining Society's New, Functional Role in Research and Innovation from Its Own Point of View

In the context of the project described above, new methods for involving society in research and innovation were developed and tested. Given that the methods and their effects and benefits have been extensively described in previous papers,[47] this article focuses on the participants and their general views about participation in research and innovation. An analysis of the general role of the actor society in Quadruple Helix innovation processes was part of this project. Since *Shaping Future* did not focus on a specific technology, it was possible to investigate overarching requirements for participative technology development processes.

Being qualitative in character, this study was characterized by the principle of openness[48] and therefore particularly suitable for uncovering public preferences toward participation that were previously unknown. This made it possible for us to deduce how participatory processes can be successfully shaped.

About four weeks after the workshops, *Shaping Future* participants were invited for personal interviews. The invitation was accepted by 50 individuals: 23 men and 27 women between 17 and 77 years old from a variety of occupational backgrounds, including clergy, teachers, stylists, engineers, researchers, psychotherapists, insurance agents, and creative professionals as well as students, freelancers, and retirees. A certain amount of self-selection within the sample, inevitable in qualitative research, was not regarded as a weakness, but as an additional source of insight into laypersons' preferences towards participation.

The individual, semi-structured and problem-centered[49] interviews lasted between 30 and 45 minutes and pursued the uncovering and reconstruction of individual interpretations, perspectives, and positions with regard to the value of participation as well as its desirable goals and forms.

A pre-prepared interview guide was used to structure the interviews around questions regarding the role of civil society within Quadruple Helix innovation processes. We developed the interview guide on the basis of the theoretical framework and research question as presented above. While interviewees were encouraged to speak freely, certain communication techniques such as narrative questions were employed to help them better articulate their opinions and allow for both inductive and deductive insights.

In preparation for the qualitative analysis, we transcribed the interview records. Relevant information was extracted and organized using Phillip Mayring's method of qualitative content analysis[50] and then interpreted using an adaption of Jochen Gläser's and Grit Laudel's method.[51]

In addition, we developed a layperson typology on the basis of the empirical analysis as well as theoretical assumptions according to Susann Kluge's method of empirically grounded typology construction,[52] also based on previous work by Allen Barton and Paul Lazarsfeld.[53] The types presented below should therefore be

Bartling and Sascha Friesike (Cham: Springer International Publishing, 2014), 17–47.

24 Hippel, *Sources of Innovation*.

25 Chesbrough, *Open Innovation*.

26 Eric von Hippel, *Democratizing Innovation* (Cambridge, MA: MIT, 2005).

27 Edler and Georghiou, "Public Procurement and Innovation."

28 Ibid.

29 Directorate-General for Communication (European Commission), *Special Eurobarometer 419: Public Perceptions of Science, Research and Innovation* (Brussels: European Union, 2014), dataset, accessed May 3, 2019, http://data.europa.eu/euodp/en/data/dataset/S2047_81_5_419_ENG; Directorate-General for Communication and Directorate-General for Research and Innovation, *Responsible Research*.

30 Wissenschaft im Dialog, "Wissenschaftsbarometer 2016," accessed May 3, 2019, https://www.wissenschaft-im-dialog.de/projekte/wissenschaftsbarometer/wissenschaftsbarometer-2016/.

31 WissensCHaftsbarometer Schweiz, "WissensCHaftsbarometer 2016," accessed May 3, 2019, http://www.wissenschaftsbarometer.ch/ergebnisse-resultats/.

32 Brabham, "Motivations."

33 M. Jordan Raddick et al., "Galaxy Zoo: Exploring the Motivations of Citizen Science Volunteers," *Astronomy Education Review* 9, no. 1 (2010): 1–15, DOI: https://doi.org/10.3847/AER2009036.

34 Gene Rowe and Lynn J. Frewer, "Evaluating Public-Participation Exercises: A Research Agenda," *Science, Technology & Human Values* 29, no. 4 (2016): 512–56, DOI: https://doi.org/10.1177%2F0162243903259197.

35 David Collingridge, *The Social Control of Technology* (London: Pinter, 1982).

36 Ortwin Renn, "Neue Technologien, neue Technikfolgen: Ambivalenz, Komplexität und Unsicherheit als Herausforderungen der Technikfolgenabschätzung," in *Neue Technologien in der Gesellschaft: Akteure, Erwartungen, Kontroversen und Konjunkturen*, ed. Christian Kehrt et al. (Bielefeld: Transcript, 2011), 63–76.

understood as generalized. Although individual cases may deviate from these types in one or more respects, they remain useful in understanding and explaining the motivation of laypersons participating in Quadruple Helix networks.

Because of the qualitative character of this study, our goal was not to gather a representative sample of opinions, but to assess and describe, as precisely as possible, the given situation and its specifics.[54] Our findings therefore reflect particular patterns identified through theoretical and analytical generalizations.[55] Those generalizations are based on similarities and differences extracted from the interviews.

Findings: The Societal Perspective on Participatory Research and Innovation

In 50 interviews, we investigated which model of collaboration between civil society and research was preferred by the laypersons themselves to create a better understanding and explanation for what had been a vaguely formulated desire for greater societal involvement in research and innovation. Firstly, the results provide information on the motives and goals that laypersons associate with their engagement in research. This allows a functional role to be more clearly defined, which – from a societal perspective – should form the basis of the collaboration between science and society. Secondly, the interviews show the basic parameters within which the interviewees were willing to contribute their time, thoughts, and ideas to research as a resource. Third, we can describe the added value that results from their participation from the point of view of the non-professional individuals themselves. These three results we present below.

Desirable Participation: Wider Discussion Rather Than Public Votes

It is perhaps unsurprising that researchers often resist the idea of public participation[56] and fear that it may undermine research quality. Perhaps more surprisingly, participants in this study often expressed similar opinions and generally anticipated that public votes would be counterproductive.

> "Participation, yes, co-decisions, not so sure. I wouldn't say 'democracy' in the sense that everyone gets to tell researchers what to do."

Most regarded the freedom of scientific inquiry as a key feature of liberal democracy.

> "Thinking is supposed to be free. Wouldn't it be awful if philosophers were no longer allowed to think without our approval? If we slapped them on the hand every time we believed their thoughts were wrong or dangerous? Or researchers, they are working on something, and we come and tell them, 'no, not on that.' We can't do that."

Many interviewees believed that outstanding researchers would be likely to leave the country, thereby ultimately undermining its capacity for innovation, should their freedom be curtailed.

Participants also voiced concern that the public may simply lack the necessary information to fully understand the subject under study, particularly with regard to basic research, and would have to rely on their gut instincts in most cases. Operating outside their area of confidence might lead to a reliance on the media, who could then exert excessive influence and ultimately obstruct the most daring, highly complex scientific endeavors – precisely those that are most likely to result in innovation.

> "The people who produce the most brilliant ideas can often only be understood by the very few people like themselves. And then there'd be all these skeptical

37 Marie Heidingsfelder et al., "Shaping Future: New Methods for Participatory Technology Foresight," in *The Next Horizon of Technology Assessment: Proceedings from PACITA 2015 Berlin*, ed. Constanze Scherz et al. (Prague: Technology Centre ASCR, 2015), 145–50, available at https://www.oeaw.ac.at/ita/en/publications/ita-books/pacita-2015-proceedings/.

38 Die Bundesregierung, *Forschung und Innovation für die Menschen: Die Hightech-Strategie 2025* (Berlin: Bundesministerium für Bildung und Forschung (BMBF), 2018), 1–66, accessed May 3, 2019, https://www.bmbf.de/upload_filestore/pub/Forschung_und_Innovation_fuer_die_Menschen.pdf; European Commission, *Horizon 2020*, 1–14; Wissenschaftsrat, *Wissens- und Technologietransfer*, 1–52.

39 Jesper Simonsen and Toni Robertson, eds., *Routledge International Handbook of Participatory Design* (Abigdon: Routledge, 2012).

40 Hella von Unger, "Partizipative Gesundheitsforschung: Wer partizipiert woran? [79 Absätze]," *Forum Qualitative Sozialforschung/Forum: Qualitative Social Research* 13, no. 1 (2012): Art. 7, DOI: https://doi.org/10.17169/fqs-13.1.1781.

41 Ellen Balka, "Participatory Design in Women's Organizations: The Social World of Organizational Structure and the Gendered Nature of Expertise," *Gender, Work & Organization* 4, no. 2 (1997): 99–115, DOI: https://doi.org/10.1111/1468-0432.00027; Kim Halskov and Nicolai B. Hansen, "The Diversity of Participatory Design Research Practice at PDC 2002–2012," *International Journal of Human-Computer Studies* 74 (February 2015): 81–92, DOI: https://doi.org/10.1016/j.ijhcs.2014.09.003.

42 Froukje Sleeswijk Visser et al., "Contextmapping: Experiences from Practice," *CoDesign* 1, no. 2 (2005): 119–49, DOI: https://doi.org/10.1080/15710880500135987.

43 Elizabeth B.-N. Sanders and Pieter Jan Stappers, "Co-creation and the New Landscapes of Design," *CoDesign* 4, no. 1 (2008): 5–18, DOI: https://doi.org/10.1080/15710880701875068; Claudia Mareis, *Design als Wissenskultur: Interferenzen zwischen Design- und Wissensdiskursen seit 1960* (Bielefeld: Transcript Verlag,

people like myself, who'd veto potentially the best solutions before they could even get a chance to be considered. What a roadblock that would be! No, no public votes, better not."

Moreover, the interviewees expressed doubt that representative participation would be practically feasible in the first place, because some groups, such as farmers, sales staff, and medical practitioners, may simply lack time or interest, thereby giving vocal minorities the space to shift the focus toward their own comparatively narrow interests.

At the same time, the participants considered themselves direct recipients of innovation or technology "pushes." One prominent example is *Industry 4.0*, which describes a current trend of automation and data exchange in manufacturing technologies, intended to enable a network of fully computerized, smart factories which will likely revolutionize a broad range of occupations. The interviewees often argued, occasionally from the taxpayer perspective, that such inventions may have ramifications too radical for them to continue unfolding behind closed doors. Accordingly, they advocated for the public's right to more advance notice and expressed the desires for more open communication on the part of the scientific community.

"I am worried that technologies developed by a small number of people will affect us all. It's all about a dialogue between the scientific community and the public. When they let us know what they're doing it won't be a secret anymore, unregulated. That's how people see it sometimes. Or they think something dangerous is being developed while they are supposed to just stand there without a say."

Such transparency, however, was desired not only as an end unto itself, but as the foundation for wider discussions about both short- and longer term innovation trajectories. The goal would not be to regulate these trajectories, as discussed above, but to offer a variety of groups the opportunity to introduce their considerations.

"We as the public would need to discuss which scientific and technological developments we'd want to see. The voice of the people, those whom it may affect, must be heard. They'd need to be able to express their desires and concerns, as feedback to the experts."

These experts, who should carefully listen to the "voice of the people," would include not only the researchers and research institutions directing the trajectories, but also the policymakers and funding agencies who initiate foresight and agenda-setting processes and thus exert a strong influence over this process. Experts should continue making the decisions, but they should increasingly consider public preferences while doing so.

Once these decisions result in concrete inventions, however, the public should have the right to co-regulate their use.

"When projects or innovations are introduced to the market, that's when being able to have a say starts mattering to me. The user should have the right to veto. Before that point, anything goes."

These findings suggest that increased attention to public preferences should lead to more welcome innovations and thus benefit the scientific community as well.

Layperson Motivational Typology

While strongly advocating for increased public involvement in general, participants always carefully weighed the personal benefits and costs associated with a given

2011); Marie L. Heidingsfelder et al., "Expanding Participation: Participatory Design in Technology Agenda-Setting," in *PDC '16: Proceedings of the 14th Participatory Design Conference: Short Papers, Interactive Exhibitions, Workshops–Volume 2*, ed. Rachel C. Smith and Anne M. Kanstrup (New York: ACM, 2016): 25–28, DOI: https://doi.org/10.1145/2948076.2948087.

44 Ikujiro Nonaka, "The Knowledge-Creating Company," *Harvard Business Review* 69, no. 6 (2007): 96–104, available at https://hbr.org/2007/07/the-knowledge-creating-company; Bart Nooteboom et al., "Optimal Cognitive Distance and Absorptive Capacity," *Research Policy* 36, no. 7 (2007): 1016–34, DOI: https://doi.org/10.1016/j.respol.2007.04.003; Scott E Page, "Making the Difference: Applying a Logic of Diversity," *Academy of Management Perspectives* 21, no. 4 (2007): 6–20, DOI: https://doi.org/10.5465/amp.2007.27895335.

45 Philipp Mayring, *Qualitative Inhaltsanalyse: Grundlagen und Techniken* [Qualitative Content Analysis: Fundamental Principles and Techniques] (Weinheim: Beltz, 2010).

46 Ibid., 12.

47 Marie Heidingsfelder et al., "Shaping Future—Adapting Design Know-How to Reorient Innovation towards Public Preferences," *Technological Forecasting and Social Change* 101 (December 2015): 291–98, DOI: https://doi.org/10.1016/j.techfore.2015.03.009; Heidingsfelder et al., "Expanding Participation," 25–28; Marie L. Heidingsfelder et al., "New Ways of Thinking about the Future Design Fiction for Public Reflection to New and Emerging Technologies," *Iterations*, no. 5 (2017): 44–51, available at http://hdl.handle.net/10344/6741.

48 Uwe Flick et al., eds., *Qualitative Forschung: Ein Handbuch*, 8th ed. (Reinbek: Rowohlt, 2010); Siegfried Lamnek, *Qualitative Sozialforschung: Lehrbuch*, 5th ed. (Basel: Beltz, 2010).

49 Andreas Witzel, "The Problem-Centered Interview," *Forum: Qualitative Social Research* 1, no. 1 (2000): article 22, DOI: https://doi.org/10.17169/fqs-1.1.1132; Christel Hopf and Elmar Weingarten, eds. *Qualitative Sozialforschung* (Stuttgart: Klett-Cotta, 1993): 15.

participatory opportunity. Many cited a lack of time or overriding personal or professional obligations as deterrents, regardless of age, sex, or background.

> "To me, it's all a question of time. I have small children and a full time job. I would need to take a day off for such things. So that's the question: how do I spend my vacation – on myself, my kids, or the science, meaning the public?"

On the other hand, neither the compensation offered nor the opportunity to contribute to science was a particularly compelling benefit. What did make it worth their time and effort was the hope of experiencing enjoyment and appreciation for their input during the event and also the prospect of having something to take away from the experience. The following layperson typology describes these preferences in more detail.

- **Type 1: the Curious** Type 1 individuals value the opportunity to satisfy their curiosity and learn. They seek to better familiarize themselves with the subjects they consider significant, such as Artificial Intelligence or the workplace of the future. While these do not directly relate to their daily lives, they have already acquired some information through open lectures, internships, popular science articles, and so forth. They now desire a discussion with other individuals through which they can mobilize their learning and refine their opinions. This type can be found throughout the entire sample, and has two subtypes.
  - **Type 1A:** individuals who seek exchanges with other laypersons, preferably long, detailed, and often concerning controversial subjects such as Industry 4.0 described above.
  - **Type 1B:** individuals interested in hearing about "what's going on" and "what the plan is" from the scientific community, firsthand.

- **Type 2: the Enthusiasts** Type 2 individuals seek not only to share their considerations with the scientific community but to see their thoughts addressed. They often believe that possible inventions might be someday affecting them personally. The subject matter typically first came to their attention during college, encouraging them to look into scientific papers and have discussions in their social circles. By this point, they have developed a strong personal position. They now wish to express this position directly to the researchers, preferably on equal terms, at length, and with even more deliberate references to their sources than is the case with Type 1. While aware of the "non-scientific" character of their input, they need to feel not only that it is welcome, but positively desired by researchers. Even more, these individuals want to receive feedback, both with regard to the content and to the ways in which the input will be employed. They regard clear and "believable" descriptions of the ways this will take place as one major reason to participate, while also experiencing disappointment in the face of less welcoming attitudes toward lay input. This type was only found among 24 to 33 year-old participants.

- **Type 3: the Fellow Experts** Type 3 individuals are "fellow experts doing their jobs." They regularly attend participatory events in the hope of advancing aspects of their own work, which they see as related. This type has two subtypes and can be found among particular occupational groups within the sample.
  - **Type 3A:** individuals who are either creative professionals or researchers from somewhat related fields looking for inspiration and new information.

50 Mayring, *Qualitative Inhaltsanalyse*.

51 Jochen Gläser and Grit Laudel, *Experteninterviews und qualitative Inhaltsanalyse: Als Instrumente rekonstruierender Untersuchungen*, 3rd ed. (Wiesbaden: VS Verlag für Sozialwissenschaften, 2009).

52 Susann Kluge, *Empirisch begründete Typenbildung: Zur Konstruktion von Typen und Typologien in der qualitativen Sozialforschung* (Opladen: Leske und Budrich, 1999); Susann Kluge, "Empirically Grounded Construction of Types and Typologies in Qualitative Social Research," *Forum: Qualitative Social Research* 1, no. 1 (2000): 1–11, DOI: https://doi.org/10.17169/fqs-1.1.1124.

53 Allen Barton, "The Concept of Property-Space in Social Research," in *The Language of Social Research: A Reader in the Methodology of Social Research*, ed. Paul F. Lazarsfeld and Morris Rosenberg (New York: Free Press, 1955), 40–53; Paul F. Lazarsfeld and Allen Barton, "Qualitative Measurement in the Social Sciences: Classification, Typologies, and Indices," in *The Policy Sciences*, ed. Daniel Lerner and Harold D. Lasswell (Stanford: Stanford University Press, 1951), 155–92; Paul F. Lazarsfeld, "Some Remarks on the Typological Procedures in Social Research," *Zeitschrift für Sozialforschung* 6, no. 1 (1937): 119–39, DOI: http://dx.doi.org/10.5840/zfs193761137.

54 Kurt Lewin, "Der Übergang von der aristotelischen zur galileischen Denkweise in Biologie und Psychologie," *Erkenntnis* 1, no. 1 (1930): 421–66, DOI: https://doi.org/10.1007/BF00208633.

55 Aglaja Przyborski and Monika Wohlrab-Sahr, *Qualitative Sozialforschung: Ein Arbeitsbuch* (München: Oldenbourg, 2014); Kurt Lewin, *Gesetz und Experiment in der Psychologie* (1927; Darmstadt: Wissenschaftliche Buchgesellschaft, 1967).

56 Strohschneider, "Zur Politik der Transformativen Wissenschaft."

- **Type 3B:** individuals who are either researchers or active citizens who often organize such events themselves and are seeking to improve their methods.

Both subtypes distinguish themselves from the other, more "typical" participants by emphasizing their expertise, but are unconcerned with sharing their opinions. Rather, they observe the process while waiting for the results. The more innovative they consider these to be, the higher their satisfaction.

- **Type 4: the Creativity Seekers** Type 4 individuals "just want to engage in creativity for a day." They have academic backgrounds and are often students or retirees and thus have comparatively flexible schedules and ample time. Having little to no familiarity with the subject matter, they feel appreciated when personally invited to the event.

  As participants, they take pleasure alternating between diverse, mentally engaging activities, especially when they see their creativity boosted and horizons broadened. They enjoy sharing such activities with people from outside of their typical social circles, preferably with those of wide-ranging ages and backgrounds, and are particularly pleased when this leads to new friendships.

These findings suggest that laypersons value particular participatory opportunities such as that for sharing educational, quality experiences with interesting people. Only a comparatively small proportion of participants, all under 35 and assigned to Type 2, wished to co-determine research trajectories. Most saw playing their participatory part in contributing to widely-shared discussions.

Gender Differences

Virtually unanimous in their opinions about desirable forms of participation, men and women in this study often differed in opinion about general value and necessary levels of participation. Female participants more frequently expressed the desire for research trajectories to be aligned with public preferences.

> "And it just so happens that even when possible technologically, many things fail because they're not welcome by potential users or other people concerned. One's solutions can respond to people's needs or one just needs what one needs, wants what one wants, or seeks to accomplish. I'd like to see solutions developed for people and not just for the technological advancement's sake."

Male participants, on the other hand, more frequently argued that the focus should be maintained on innovative qualities, particularly those that are only now becoming possible because of previous achievements. Moreover, they often doubted the value of lay input in the first place.

> "How scientists can put this to a good use is more than I can imagine. I don't really believe they can [use lay input] because they are much smarter than us. Anything we can possibly think of, they've already figured it out."

Men also believed that the main purpose of participation lay in giving the public the opportunity to better familiarize themselves with current and expected developments and that expertise should remain these developments' primary foundation because "laypersons may just be reinventing the wheel."

While similarly considering expertise indispensable, the women were nevertheless convinced that it could, and should, be supplemented by different lay opinions:

> "I think that science often happens in a bubble. Whether it'll be good for people should be for the people to decide. There are experts in technology and there are experts in 'the everyday,' which they get from everyday experiences. Their feedback is important, too. I have a great respect for experts, but [the idea] of them developing technologies among themselves … inside their bubble … that's just scary."

These findings suggest that women ascribe a greater value to participation and also reflect those of other studies indicating that women may have more welcoming attitudes toward heterogeneous, research-related collaboration as well as toward diversity in general.[57]

Conclusions

In the absence of clearly defined goals, the grand, politically driven call for greater public involvement in research and innovation may lead to confusion on the part of each Quadruple Helix actor and ultimately undermine this pursuit. Because it might be interpreted as a call for public inclusion in decision making, researchers – particularly in certain, highly complex fields of basic research – might anticipate curtailments of their freedom to research and therefore object to any form of participation and transdisciplinary exchange. In addition, the unclearly defined role of society in the Quadruple Helix Innovation System also poses a challenge to the proper formulation of goals and application of appropriate methods to participatory processes. If participation in research and innovation takes place without clear roles and objectives (beyond funding policy guidelines), this can lead to greater frustration on the part of researchers, research funders, and ultimately the laypersons involved.

The laypersons in this study, on the other hand, had very clear and specific ideas about the ways they wished to be involved. Similar to many researchers, they suspected public inclusion in decision making would be counterproductive and believed that experts should continue to determine research trajectories. At the same time, participants expressed the desire for more open communication on the part of the scientific community and for lay input to be more welcome and more deliberately utilized. They believed that public participation should take the form of broader and more extensive discussions, not only about proposed developments, but also about desirable socio-technological futures.

We can draw two conclusions about the design of participatory approaches from these results. Firstly, it is important to base collaboration on an elaborate understanding of functional roles within the Quadruple Helix and ensure that all actors involved share this understanding. In this way, resistance to societal participation in research and innovation can be reduced and successful dialogue formats between research and society can be designed.

Secondly, it becomes apparent that statistical representativeness, which is seen as a major challenge for participatory approaches, should not be seen as an obstacle to participation, since the involvement of laypersons is not a matter of democratic decisions on research trajectories. In order to enrich academic mode 1 knowledge with societal mode 2 perspectives, the diversity of participants is the far more relevant criterion for the quality of participative approaches.

Finally, our findings indicate that rather than being able to contribute to science or receiving financial incentives, laypersons are motivated by educational, mentally engaging experiences they can share with interesting people. Researchers can therefore design compelling participatory projects by inviting individuals from diverse backgrounds, employing original methods, and highlighting the value of the subject matter for both these individuals and the general public.

57 Lei Pan and Elizabeth Kalinaki, "Mapping Gender in the German Research Arena" (report, Elsevier Analytical Services, 2015), uploaded October 27, 2015, https://www.elsevier.com/research-intelligence/resource-library/gender-2015; Giovanni Abramo et al., "Gender Differences in Research Collaboration," *Journal of Informetrics* 7, no. 4 (2013): 811–22, DOI: https://doi.org/10.1016/j.joi.2013.07.002; Joyce F. Benenson et al., "Rank Influences Human Sex Differences in Dyadic Cooperation," *Current Biology* 24, no. 5 (2014): 1, DOI: https://doi.org/10.1016/j.cub.2013.12.047; Diana Rhoten and Stephanie Pfirman, "Women in Interdisciplinary Science: Exploring Preferences and Consequences," *Research Policy* 36, no. 1 (2007): 56–75, DOI: https://doi.org/10.1016/j.respol.2006.08.001.

The empirically grounded typology gives more detailed indications as to how participatory formats in research and innovation should be designed so as to offer incentives for the motivations driving the various types. In order to meet the goals and motives of the Type 1, participative formats must be designed as a bidirectional exchange of mode 1 and mode 2 knowledge. It is not enough to integrate society's knowledge into academic research. Instead, scientists must increase their capacity to communicate the results of their research to non-experts. The designers or enablers of these participatory formats must also create sufficient space for discussion among workshop participants so that they can further develop their views via exchanges with others. Type 2 needs clear communication about the process design of the research format. It is not sufficient to announce that the societal perspective is being heard and will – in some abstract way – influence future decisions. Instead, workshop hosts should illustrate the process design underlying the exchanges among experts and non-experts, how the societal perspective will be transferred to experts or decision makers, and to what extent it may have an impact on them. In order to meet the objectives and motives of Type 3, new participatory methods must be used in co-ideational workshops. However, since the third type is less interested in bringing the societal perspective into research and innovation, they may very well impede exchanges among other group members. This could be prevented by asking participants about their motivation when registering for the workshops upfront. Type three individuals could then be invited to a separate expert discussion instead inviting them to the workshops. Type 4 highlights the importance of creating a workshop format with an appealing design. These participants are less interested in the topic of the workshop, nor do they want financial compensation for their participation. They are motivated by the framework conditions: an appreciative invitation, the design of the space and the choice of catering. Another important factor is the composition of the participant group, as participant diversity is an incentive for Type 4.

Certain groups and fields might require other, more tailored approaches to attract participants. One such group consists of those laypersons who may be affected by proposed developments but have little interest in contributing. In addition, fields like materials or optics are likely to draw only minimal public attention because of their complexity and mainly industrial application.

While participants in this study were virtually unanimous about the desirability of certain forms of participation, women more strongly wished for increased public involvement. Should similar differences be found within the scientific community, we may expect the degree to which particular research teams and institutions would be inclined to invite laypersons to their projects to strongly depend on the numbers of women and the levels of their influence within these teams. We therefore ask ourselves whether a comparatively low proportion of female decision makers in certain fields of academia may impede such inclination in general.

Future research, particularly representative and cross-national studies, can supplement our findings by producing further insight into how participatory projects can best be designed. In addition to uncovering preferences of the public, this research should also focus on those of the other Quadruple Helix actors: the scientific community, business, and the government.

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