



Strategies to Overcome Collaborative Innovation Barriers: The Role of Training to Foster Skills to Navigate Quadruple Helix Innovations

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Abstract

Quadruple Helix Collaborations (QHCs) is a cooperation model in which industry, government, academia, and the public interact to innovate. This paper analyses the impact of a training intervention to provide specific knowledge, skills, and attitudes to deal with barriers commonly found in the progress of QHCs. We designed, implemented, and evaluated three training programs in Austrian, Colombian, Danish, and Spanish institutions. We analysed trainees' ($n=66$) and trainers' ($n=9$) perceptions to identify the competencies acquired with the intervention and the approach's limitations. We used online questionnaires (35 trainees; 9 trainers), semi-structured interviews (10 trainees), and a focus group (6 trainers). Trainees answered positively regarding their self-perception about the impact of the course and highlighted the acquisition of inspiration for their practice (score 4.1 out of 5.0) and knowledge (3.7). In contrast, they perceived that a deeper interaction with other participants (2.7) was challenging. After the courses, 74% of respondents indicated that they know more about how QHCs work in practice, and 86% about collaboration or engagement methods. Moreover, participants plan to be more sensitive towards setting common goals (71%) and power imbalances (63%). Trainers' perceptions align with those expressed by participants, except that they considered that the interaction amongst participants during the course was higher. Qualitative analysis of interviews with participants and the focus group with trainers provides more detail about the strengths and weaknesses of the intervention. Our study shows that the collaborative design and implementation of training impact the participant's learning competencies, with potential implications in their medium- to long-term practice.

Keywords Collaborative innovation · Quadruple helix collaborations · Training · Multi-stakeholder

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Introduction

Collaborative forms of innovation, which connect diverse institutions and actors in new constellations, are generally expected to enhance the capacity to effectively address contemporary societies' grand challenges worldwide (Bryson et al., 2006). The assumption is that complex societal problems cannot be tackled by single organisations and players in one sector alone, but that new forms of cooperation and innovative solutions are needed to solve global challenges (Bryson et al., 2006; Morawska-Jancelewicz, 2022). These complex problems are quite varied and connect to, amongst others, the fourth industrial revolution, clean energy production, sustainable mobility, pandemic responses, and food production. Due to their complexity and interrelatedness, these challenges cannot be handled by one single actor with one set of tools and methodological approaches but instead call for collaborative problem-solving (Head & Alford, 2015; Lopes & Franco, 2019; Suominen et al., 2018), and they critically require the involvement of civil society actors (Anthony, 2023). Citizens and civil society organisations are often confronted with these issues and their consequences in concrete local settings. They can therefore provide contextual insights and collective intelligence that refine plans and actions that are important to context-specific adjustments, communal ownership, and sustainable solutions (Braun et al., 2021a).

One way to frame the efforts of civil society to address complex issues is collaborative innovation. Collaborative innovation is a growing phenomenon in which various actors from different fields and interests work together because of the need to solve wicked problems (Braun et al., 2021a). Previous studies have shown that some SMEs allocate only a small percentage of their investment budget to collaboration with external companies or other organisations. However, they receive a significant return on investment from such partnerships, almost four times compared to companies that do not collaborate (Hindi & Frenkel, 2022). The apparent quantifiable benefits from collaboration become clear in the high-technology company setting, as presented by Hindi and Frenkel (2022). However, it remains to be seen if such benefits occur for different fields and collaborations.

The Quadruple Helix Collaboration Model for Innovation

At the heart of collaborative innovation efforts lies the idea that information, resources, and knowledge have to be shared in ways that help generate the best ideas, solutions, and innovations that are more inclusive and oriented towards actual societal needs. Collaborative innovation emerges under a variety of names: from open innovation (Chesbrough, 2003), co-creation (Frow et al., 2015), co-innovation (Popa et al., 2020), and Responsible Innovation (Stilgoe et al., 2013) to Quadruple Helix Collaboration (Carayannis & Campbell, 2009, 2010).

For this paper, we focus on Quadruple Helix Collaborations (QHCs) as a model for collaborative innovation because it provides a framework that focuses on institutionalised actors and addresses the lack of civil society engagement in a way that allows us to identify additional actors through organisations. QHCs

are defined as an innovation cooperation model in which the four major sectors of society — industry, government, research institutes, and the public — interact to produce innovations (Arnkil et al., 2010; Carayannis et al., 2022). QHCs have received increased attention in the past decades due to their promise of increased efficiency and responsibility (European Committee of the Regions et al., 2016). The concept recognises that interaction, complex interdependencies, and integration of diverse perspectives and actors are crucial for the success of an innovation system (Carayannis & Campbell, 2009; Etzkowitz & Leydesdorff, 2000). However, there is a lack of empirical support in the application of QHC to the innovation setting, and innovation practitioners often lack references on how to overcome the number of challenges that arise in such cross-sectoral collaborations, which can increase the likelihood of collaboration failures and mistrust between involved actors (García-Terán & Skoglund, 2019). These potential risks and challenges should be actively addressed — both at the beginning of a collaborative process and continuously throughout the innovation process — to navigate the partnerships in ways that enable them to thrive and succeed.

Amongst others, one critical issue in QHCs is the involvement of civil society, both as individual citizens or structured in civil society organisations (CSOs). The involvement of civil society in research and innovation constellations provides concrete yet diverse benefits by bringing diverse perspectives and insights regarding the needs of users and customers, stimulating creativity, and drawing attention to ethical, environmental, and social implications of scientific knowledge and technologies that might otherwise be more or less neglected (Braun et al., 2021a; Carayannis & Rakhmatullin, 2014; Cavallini et al., 2016; Dominique Foray et al., 2012). Moreover, according to theory, the involvement of the fourth helix can be used to support the transition to new models of industry and society, more inclusive and sustainable (Carayannis et al., 2022).

Despite the potential benefits of involving civil society in a collaborative innovation process, such involvement presents an additional challenge to the collaboration, as civil society has a different orientation and value creation idea (Blok & Lemmens, 2015; Popa et al., 2020). The investigation of real-life QHCs has shown that the challenges to set up collaborations with strong involvement of civil society actors emerge at three major levels: (i) the activity, (ii) the governance, and (iii) the systemic level (Braun et al., 2021a). The activity level (i) refers to when actors intending to open up their innovation and research processes are confronted with stakeholder engagement and involvement questions. The challenge at this level is to correctly identify who should and can be involved from the fourth helix and in what ways, as civil society is quite diverse and includes various actors and institutions. At the governance level (ii), the challenge arises in the availability of resources and skills for civil society actors, which hinders their ability to contribute to innovation activities on equal footing. Finally, at the systemic level (iii), the challenge is shifting innovation's central value from economic profit to societal impact. These challenges call for new tools, skills, and strategies that support the inclusion of civil society in innovation processes and, more generally, the establishment and successful navigation of QHCs or other forms of collaborative innovation.

Training for Collaborative Innovation

Findings from previous work in the related field of Responsible Research and Innovation have shown the importance of individual training to promote practical skills and deliberations that allow researchers and innovators to engage in new ways of working (Mejlgaard et al., 2019; Tokalić et al., 2021). Moreover, other studies in the field of healthcare have shown that formal training improves group- and organisational-level innovativeness (Schultz et al., 2017). Although the latest study has limitations and potential biases regarding the field of applicability, the randomised selection of participants, the time frame, and the lack of a control group, it provides ground for the impact of using training to develop innovation skills and strategies in a set of people. Therefore, we hypothesise that intervening at the individual level and giving training will enable innovation agents to engage in quadruple helix collaborations and help them overcome the challenges that arise in the process.

Our study fills a significant gap in existing research and practice with innovation practitioners and policymakers as, to the extent of our knowledge, there are no training programmes to approach collaborative innovations systematically and to deal with different stakeholders with different value frames to work on a common goal. Yet, there has been some experimentation with training in skills needed for QH collaborations, such as in the EU-funded research programme RiConfigure which established five social labs (Timmermans et al., 2020) in different countries in Europe and South America. As part of the actions developed inside these social labs to tackle a particular challenge (e.g. energy, mobility, industrial automation, agriculture) through collaborative innovation, researchers included some dedicated training sessions on collaboration facilitation, stakeholder identification, and role-playing. From their experience, they concluded that a more consistent training of practitioners in the advantages and the methodology of QHCs could empower some actors in the collaboration to achieve their objectives (Braun et al., 2021a). Therefore, our goal is to evaluate the impact of training programmes on acquiring learning competencies for collaborative innovation. We describe the process for designing, testing, and evaluating three training programmes to overcome QHC innovation barriers, reflect on the potential of training to support collaborative innovation processes, and provide a framework to replicate training experiences in the field and explore new lines of research.

Despite theoretical advancement in understanding collaborative innovation dynamics and the benefits of involving civil society actors in innovation, there is a clear gap in practical resources that support real — and highly complex — innovation processes. Thus, we examine in this research the design of training programmes to support collaborative innovation in Quadruple Helix Collaborations and evaluate their impact and usefulness to develop skills, increase knowledge, and set the mindset required to engage in such innovation processes. By building on practical experience and a pedagogical framework, we are providing a further understanding of the factors that may influence the implementation of QHCs. We also recognise the model's limitations and the tools available to support practitioners in engaging in more collaborative and democratic forms of innovation. Our results will enable innovation practitioners and policymakers to acknowledge the use of training programmes in collaborative innovation efforts and be better equipped to overcome the challenges that arise at the individual level.

This paper is structured as follows: the “[Methodology](#)” section presents the research strategy for the design, testing, and evaluation of three training programmes to promote collaborative innovation; the “[Results](#)” section contains the data derived from the training interventions; and the “[Discussion](#)” section analyses the implications of our results, the impact of training at the individual level to support QHC innovation processes and overcome common barriers, and the limitations of our approach. Lastly, the “[Conclusions, Implications, and Future Research](#)” section describes some final considerations, implications of the study for innovation practitioners and policymakers, and insights for future work.

Methodology

Training Design

Three training programmes were designed to foster the capabilities to initiate and navigate collaborative innovations. To do so, we followed a participatory process and a need-based approach. Participatory design is based on collaboration, co-creation, and empowerment with users (Hartson & Pyla, 2018). In this case, users are innovation practitioners and policymakers contributing to the design process. This allows them to suggest ideas, provide feedback, and participate in decision-making. This approach aims to create a product (i.e. training) that accommodates their needs (i.e. need-based) and helps them achieve their goals. The method is also known as co-operative design, co-design, community design, or community-based participatory research (Elizarova & Dowd, 2017).

To identify the needs of innovation practitioners and policymakers and involve them in the design of training, we used three layers: (a) applied research findings from social labs; (b) co-design with practitioners in dialogical events; and (c) input from existing resources in related areas of theory or practice.

(a) Applied research findings from social labs

We gathered research findings from five social labs established within the research project RiConfigure (Braun et al., 2021b). We followed the experiences and learnings from five social labs as they developed interventions for five real-life Quadruple Helix Collaboration projects throughout Europe and Colombia over 1.5 years. Key aspects identified from these experiences were put together to draft the content of the training programmes. Then, we contrasted and adjusted the draft content of the training to include the findings from a comparative analysis of 72 QHC cases (Popa et al., 2021).

(b) Co-design with practitioners in dialogical events

We collected input on challenges and needs from more than 150 innovation practitioners and policymakers representing all four sectors of the Quadruple Helix model, who participated in two in-person and two online dialogical events organised between 2020 and 2021. The inclusion criteria for this group were their connection to innovation practice or policy and their diversity regarding helix representation. At these events, researchers, practitioners, and policymak-

ers were invited to share their experience and expertise in cross-sectoral collaborative settings and express their needs and expectations for training to address encountered challenges appropriately. The information collected during these participatory processes contributed to the structural backbone of the content in the training programs.

(c) Input from related areas

We systematised open resources from related fields that could respond to training needs identified in the previous layers and included them in the training structure. We collected relevant training material about team building (Oxfam, 2007), citizen participation (World Bank Group, 2019), stakeholder engagement (Acland, 2012), public engagement (Silva & Bultitude, 2009), open innovation (Chesbrough et al., 2006), participatory action research (Torre, 2014), and Responsible Research (Owen et al., 2012) and Innovation (Blok et al., 2015; Schomberg, 2013). Finally, we partially based our work on the openly available training programmes developed by the project HEIRRI (Mejlgaard et al., 2019; RRI Tools, 2018) for collaborations in the field of RRI and on an existing manual for multi-stakeholder partnerships (Brouwer & Woodhill, 2016).

Pedagogical Methodology

The three courses are based on the pedagogical innovation method *5E's Instructional Model*, which is effective when working with heterogeneous groups (Bybee et al., 2006). The 5Es represent five sequential stages of a learning cycle: Engage, Explore, Explain, Extend (or Elaborate), and Evaluate. Participative learning approaches enrich the different stages, such as inquiry-based (Duran & Duran, 2004) and problem-based methodologies (Hmelo-Silver, 2004). We included such approaches in the training design by, for example using storytelling for problem-based learning (PBL). This allows participants to use personal processes of acquiring information to solve an innovation problem as the primary mechanism for acquiring new knowledge (Allen et al., 2011). As suggested in PBL theory, all courses couple training situations with real-life practical situations. The practical situations, also called “cases”, are based on experiences derived from the five social labs analysed in the first layer.

Training Implementation

Five different institutions in Europe and Colombia tested all courses at least once between February and April 2021. As seen in Table 1, 66 people participated in the courses, and 35 completed the evaluation questionnaires (53%). Participants to the courses were recruited by each institution responsible for the implementation. For the recruitment, each institution tried to achieve the representation of the four helices. Targeted participants mainly represented innovation networks, universities, civil society organisations, and local governments. Moreover, some participants were

Table 1 Details of the implementation of training courses

Course	Organisation	Country	Type	No. of registrations	No. of participants completing the course	No. of survey responses
Workshop	Danish Board of Technology	Denmark	Non-governmental organisation	8	8	3
Workshop	Institute for Advanced Studies	Austria	Research organisation	21	19	7
Workshop	Ludwig Boltzmann Gesellschaft	Austria	Research organisation	23	20	12
Intensive course	Universidad de Pompeu Fabra	Spain	University	19	14	7
Open online course	AvanCiencia	Colombia	Non-governmental organisation	37	5	6
			Total	108	66	35

reached out in the social labs established during the project RiConfigure.¹ Due to COVID-19, all training implementation activities had to be conducted online rather than face-to-face as initially designed. The implementation was accompanied by an evaluation survey, which was completed by 53% of the participants.

Training Evaluation

During and after the courses, we evaluated the five implementation activities to analyse the impact of these training programmes on participants and to identify aspects for improvement regarding content, structure, and moderation of the courses.

We approached the qualitative impact of training programmes based on three classical competencies (Parry, 1998). The competencies are factors that define a person's behaviour and that can be improved via training. They are, therefore, a good indicator of the impact of a particular learning process induced by training. The three competencies defined for this study were the following:

- *Knowledge*: refers to the acquisition of new information around a specific topic.
- *Skills*: refers to acquiring new tools or abilities to perform a particular action.
- *Intended change*: refers to participants' interest to engage in an acquired behaviour or modify the status quo of their practice after the course.

The evaluation process consisted of four components:

- A questionnaire about the training experience addressed to all participants of each course implementation (35 responses out of 66).
- Semi-structured interviews about the training experience. We interviewed two people per course (10 interviews) in their native language. The interviews were conducted by a person outside the course organisation team.
- A questionnaire about the training implementation process addressed to all organisers and trainers of each course (9 responses out of 9).
- One focus group about the training implementation process with organisers and trainers (6 participants, 1.5 h).

In line with data and method triangulation (Patton, 1999), this approach strengthened the validity of the data. It also enabled the development of a comprehensive understanding of the training implementation and experience and its impact. We developed the questionnaires, interview guide, and focus group guidelines with feedback from course implementers and other researchers.

¹ <http://riconfigure.eu/>

Data Analysis

The quantitative data from the questionnaires was analysed in Microsoft Excel 2010, using descriptive statistics to identify response trends. Samples are small for robust statistical analysis; however, it was possible to identify broader trends. The interviews were transcribed by the co-authors of this paper in line with the clean read/smooth verbatim transcript proposed by Mayring (2014). Interviews were then translated to English using the automatic transcription service DeepL and checked manually for automatic translation mistakes. The qualitative data from the interviews were analysed following a qualitative content analysis. This approach allows classifying written materials into identified categories. It is based on the interpretation of the content of text data using a systematic classification process of coding and identifying categories or patterns to describe the meaning of qualitative material (Schreier, 2012). This technique is useful for representing a systematic and objective phenomenon description. First, based on the objectives and learning outcomes defined in the curriculum of each course, we created 13 categories of analysis. These categories were inductively revised and adjusted from the interview data, creating the final data code frame (Table 2). Then, we used the three classical competencies of knowledge, skills, and intended change (Parry, 1998) to group such categories and frame the analysis.

The interviews were coded one by one by five co-authors, and observational notes were included in the analysis template. The qualitative data of this paper has been reduced to codes or concepts that describe the research phenomena by creating categories, i.e. groups of content that share a commonality (Elo et al., 2014). The link between quantitative and qualitative data was made by using common categories in the analysis of the questionnaires and the development of the qualitative data code frame.

To strengthen data validity, investigator triangulation and peer debriefing were used. This first strategy involved using six researchers for a more balanced perspective during the interviewing and analysis process. They first coded a sample of interviews as a means of calibration, then worked independently, achieving a high degree of reliability. Peer debriefing was used to ensure the collection of valid information. After coding, the codes of each interview were reviewed by another co-author to achieve intercoder reliability (Tinsley & Weiss, 2000). Discrepancies were discussed and resolved between coders. Finally, the categories were analysed across all codes and summarised collectively by the co-authors.

Finally, the focus group analysis was done by recording and documenting the session. This documentation was done by an independent observer who took notes on the interaction of all participants. The authors then analysed the recording and notes based on the qualitative data code frame developed for the interviews, and the results were compared to the data derived from the interview.

Results

Three training programmes were designed: a workshop, an intensive course, and an open online course (OOC). They address initiators of collaborative innovations or potential agents from all sectors of the quadruple helix. They provide formats that

Table 2 Categories of analysis and learning competencies

Learning competence	Category of analysis	Definition
<i>Knowledge</i>	Importance and relevance of QHCs	The participant mentions acknowledging the importance and relevance of collaborative action for innovation or indicates a change in their attitude towards it
	Knowledge on basic aspects of QHCs	The participant mentions an increase in basic knowledge on QHCs, for example identifying better the 4 helices and what they mean
	Deep knowledge on QHC	The participant acknowledges more detailed knowledge on empathy, communication, power management, or stakeholder engagement as important aspects for collaborative innovation
	Identify relevant examples at local level	The participant mentions having gained insights into real-life QHCs in their context
	Importance of practice examples	The participant comments on the importance of getting to know QHC practice examples to better understand QHCs and its impact or to start or navigate themselves a QHC project
	Develop skills for QHC	The participant acknowledges to have acquired new abilities to start, navigate, or push QHCs
	Interaction with other participants	The participant indicates to have gained contacts or interacted with others
<i>Skills</i>	Tools for SH engagement	The participant mentions having acquired new tools (methodologies, processes, concrete guides, or alike) to identify, engage, or collaborate with QH stakeholders
	Tools for QHC navigation	The participant mentions having acquired methodologies, strategic guidelines, tools, or alike for a QHC endeavour
	Networks	The participant mentions the wish to keep in touch with other people or create networks
	New projects	The participant indicates to have proposed a QHC in their innovation practice, to have got an idea for a new project, or to have the intention to kick-start a new project
<i>Intended change</i>	Adaptation to participants' life	The participant mentions that they have adapted the course (content, materials, or alike) to their life
	Adaptation to participants' practice	The participant mentions that they have adapted the course (content, materials, or alike) to their professional practice

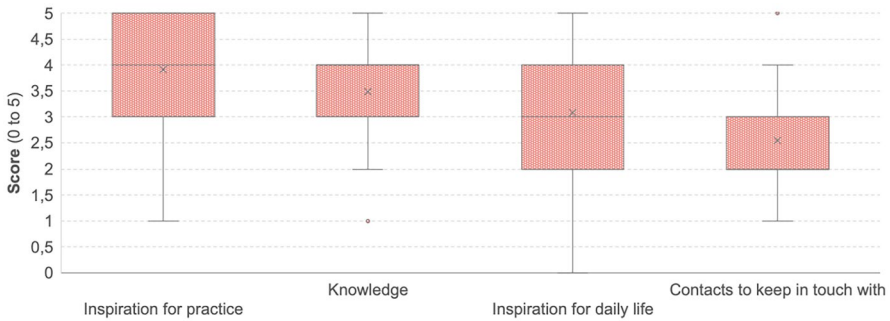


Fig. 1 Participants' rating of takeaways from the courses. The scores show the response to the question: "Please tell us your opinions about what you take away from the course. Rate the following items on a scale from 0 to 5 (0 — none, 5 — very much)". The "x" in the middle of the boxes represents the median

vary in focus, depth, and goals and can be tested for differential impact. The workshop aimed to provide participants with knowledge and tools to explore the concept of Quadruple Helix Collaborations as a way to address complex challenges and enable them to build a (regional) network of potential partners in their field. On the other hand, the intensive course intended to give a more in-depth confrontation with Quadruple Helix Collaborations by conducting mock project groups structured around a "Grand Challenge". This way, participants from different sectors could collect practical experience working in cross-sectoral collaboration. They could develop specific proposals to define or improve existing quadruple helix projects or initiatives and ideate new collaborative innovations. Finally, the OOC enabled international participants to generate fundamental knowledge on Quadruple Helix Collaborations, with a particular emphasis on including civil society actors in collaborative settings and translating such knowledge to their area of interest. The course curricula, the activities, dynamics, and training recommendations are available online and under a creative common licence to promote further use and modification.² A vast majority of participants agreed (68%) or strongly agreed (23%) that the course correlated to the goals communicated.

Quantitative Results

Respondents answered positively regarding the impact of the course, reflected in high average ratings when asked about key takeaways. Inspiration for their practice (average rating 4.1 out of 5.0) and knowledge acquisition (average rating 3.7 out of 5.0) were highly positively evaluated, receiving the highest ratings (Fig. 1). In contrast, participants perceived it was challenging to get a deeper interaction with other participants and to be able to exchange experiences and learnings based on their

² Training programmes and recommendations. Available at: <https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5e4d981c0&appId=PPGMS>

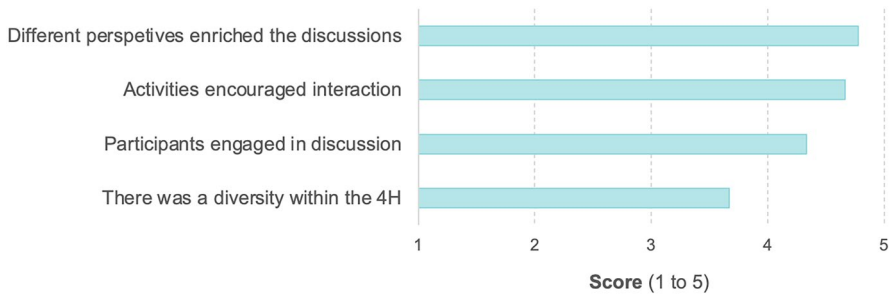


Fig. 2 Trainers' perceptions on the interaction amongst participants during the course. The scores show the response to the question: "Which QHC aspects were considered by participants in their final contributions?" The bars represent the average values

own practice. These observations are reflected in the outcome of "contacts to keep in touch with", with an average score of 2.7 out of 5.0.

The trainers perceived that the course participants offered different perspectives that enriched the discussions (average score 4.8/5.0), that the activities encouraged interaction (average score 4.7/5.0), that the participants exchanged ideas (average score 4.3/5.0) and that, in most of the cases, the participant composition was representative of the four major societal helices (average score 3.7/5.0) (Fig. 2).

Knowledge

The competence of knowledge refers to the acquisition of new information around a specific topic. After the courses, participants reported gaining basic and deep knowledge about QHCs (Fig. 3). Concretely, 74% of respondents indicated that they know more about how QHCs work in practice, 71% reported knowing more about the value of including civil society in innovation, and 51% reported knowing more about concrete aspects that influence collaborations, like power differences and stakeholder identification.

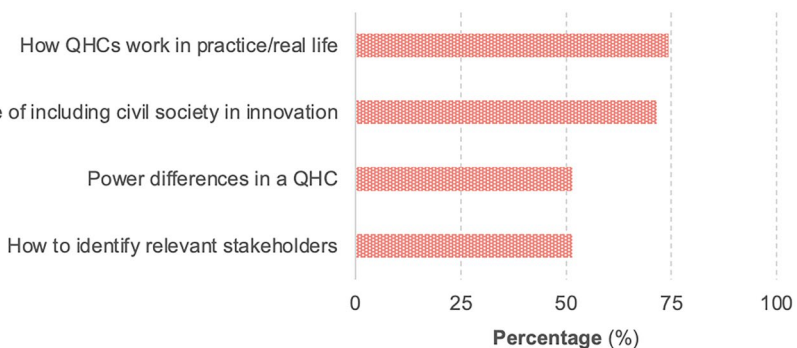


Fig. 3 Participants' knowledge after the course. The bars represent the percentage of affirmative responses to the question: "After this course, I know more about..."

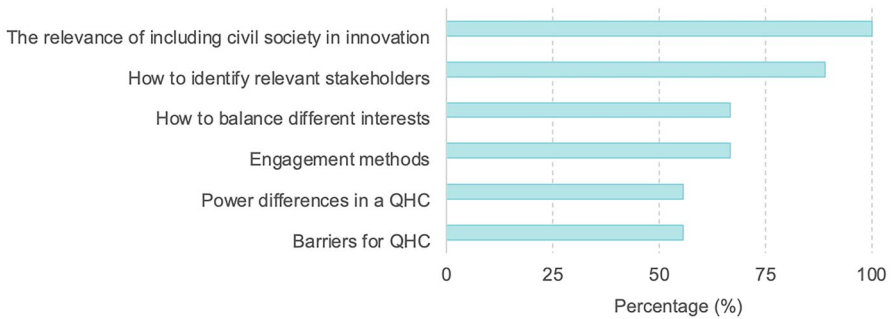


Fig. 4 Trainers' perception on the aspects considered by participants at the end of the course. The bars represent the percentage of affirmative responses to the question: "Which QHC aspects were considered by participants in their final contributions?"

We also found that, on average, 62% of the participants in the workshop and the intensive course described that they know more about "new collaboration actors in [their] area of interest". Participants in the open online course also reported having achieved knowledge of new collaboration actors (83% of respondents), even if this was not a specific goal of this type of course.

Our approach to assessing knowledge acquisition relies on self-perception, and it certainly comes with limitations. To compensate for that, we contrasted the participants' opinions on their knowledge after the course with the trainers' perception of what participants came up with in the wrap-up sessions of the courses. The results from the trainers support increased knowledge and awareness of both basic and deep aspects of QHCs and their key elements (Fig. 4). Strikingly, all trainers reported that participants considered the relevance of including civil society in innovation. Other aspects that the trainers identified as considered by the participants were how to identify relevant stakeholders (89%), how to balance different interests (67%), and engagement methods (67%). Moreover, all trainers observed that some participants in each course type were curious to hear more and go deeper into the course topics.

Skills

The second competence analysed, skills, refers to acquiring new tools or abilities to perform a specific action. Regarding acquiring tools or methodologies, 51% of respondents indicated that they know more about identifying relevant stakeholders; and 86% stated that they know more about collaboration or engagement methods. This is consistent with the observation from the trainers that most participants referred to stakeholder identification and engagement methodologies in the wrap-up sessions or activities of the courses, as seen in Fig. 4.

Under this category, we also evaluated the creation of networks and the applicability of the courses to the participant's personal and professional realms. We found that the course goal of establishing a network of potential partners representing the four major societal sectors was underachieved. When asked to score the item "I take away contacts that I will keep in touch with", respondents gave

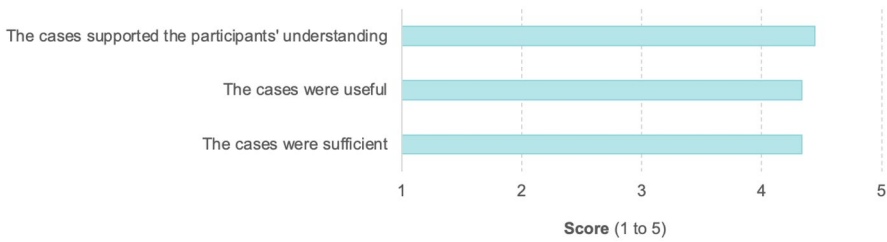


Fig. 5 Trainers' observations regarding the use of practice examples or cases (The cases are small narrations from real collaborations that explain the problem(s) each collaboration approached, who was involved, how they collaborated, etc. They are based on the experiences from the project RiConfigure: <http://www.riconfigure.eu>). The scores show the response to the question: "Rate the following statements on a scale from 1 to 5 (1 — fully disagree, 5 — fully agree)"

an average rate of 2.5 out of 5, and only 35% of the respondents answered positively when asked, "Has the course allowed you to establish collaborations with new people?". The reasons behind these results could be related to the changes that were required due to the COVID-19 pandemic: the switch from longer in-person courses with dedicated spaces and activities for networking and exchange to an online environment with major time constraints. In this regard, however, the trainers observed that the participants connected (average score 4.0/5.0). This result needs to be analysed carefully considering the participants' profiles in each course, as will be discussed later on.

Regarding the course applicability, 100% of respondents indicated that they could apply the course methods to their area of interest, and 71% reported that they could apply the practice examples to their area of interest. As seen in Fig. 5, the practice examples were also referred to by the trainers as being important for supporting the participants' understanding of the course content (average score 4.4/5.0) and being both useful (4.3/5.0) and sufficient (4.3/5.0).

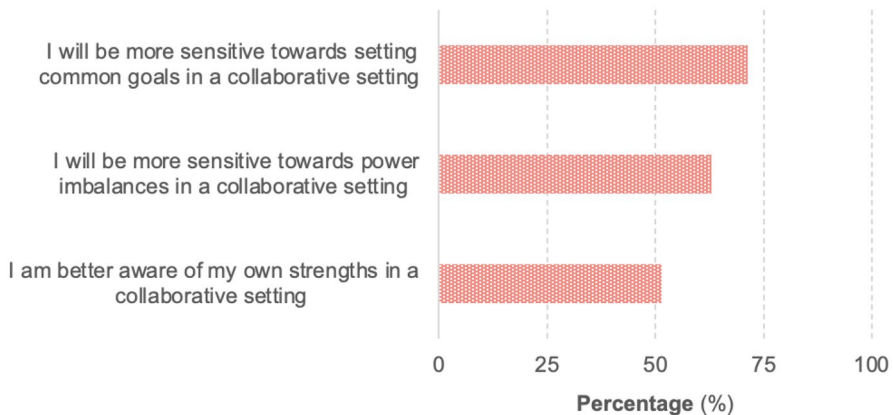


Fig. 6 Participants' attitudes after the course. The bars represent the percentage of affirmative responses to the question: "After the course, I..."

Intended Change

Under the third competence, intended change, we assessed participants' interest in engaging in an acquired behaviour or modifying the status quo of their practice after the course. Our results indicate that after the course, there is an attitudinal change in some of the crucial aspects to be considered in a collaborative innovation setting, as seen in Fig. 6. Amongst respondents, 71% plan to be more sensitive towards setting common goals, 63% will be more sensitive towards power imbalances, and 51% are better aware of their strengths in a collaborative setting.

About new projects arising during or thanks to the courses, it was interesting to find that when we asked workshop participants if the course encouraged them to create or advance in a collaborative project, the percentages of affirmative answers varied vastly amongst the three implementation experiences (71%, 25%, and 0%). We hypothesise that this largely depends on the participants' characteristics: only if the participants are innovation practitioners of the four helices (as suggested in the courses' design) can they relate to real projects and propose a QHC in their practice. However, other factors may also influence this result, like specific group dynamics during the training activities.

The participants worked in small groups during the intensive course to suggest and plan a mock QHC project. In that regard, 28% of respondents said that the mock project they worked on during the course related to a real challenge they were facing. This number can be seen as relatively low, but it may be explained due to the diverse profiles and interests of the course participants, which led them to work on projects that they all agreed on rather than on a real challenge each participant was facing.

Qualitative Results

The frequency in Table 3 indicates how many interviewees referred to each category of analysis. Four categories were mentioned by at least 80% of all interviewees: Knowledge on basic aspects of QHCs, Interaction with other participants, Tools for SH engagement, and Adaptation to participants' practice. This indicates issues of high importance for participants but might also indicate a particular bias in the interview design. Less frequent categories are also considered for this analysis, as all the identified quotes refer to relevant aspects. The data from the qualitative analysis supports the acquisition of knowledge and skills in the course participants and their intention to change some aspects of their innovation practice towards a more collaborative approach.

Knowledge

The majority of participants (60%) acknowledged and agreed on the importance and relevance of collaborative action for innovation or indicated a change in their attitude towards it. Interviewees pointed out, for example, that QHCs help foster diverse and inclusive, as well as holistic thinking and have the potential to contribute to societal changes.

Table 3 Main qualitative results according to each training competence and categories within them

Training competence	Category	Frequency (/10)	Summary of results and relevant quotes
<i>Knowledge</i>	Knowledge on basic aspects of QHCs	10	Participants reported increasing their knowledge in the different categories. The baseline knowledge level influenced the courses' impact on participants, particularly in the category of basic QHC knowledge. Cases and practice examples and the interaction between participants are key. Through discussions with each other, participants gained new perspectives, which triggered a fruitful exchange.
	Deep knowledge on QHC	7	"I have no experience in collaborative innovation and therefore have learned, because it was very new. (IC_I)"
	Importance of practice examples	7	"It was by the end of the course where we had the best case (...) it just emphasises the theory and brings the theory to life. (WK_H)"
	Importance and relevance of QHCs	6	The courses provided participants with a more holistic and systematic view of collaborative innovation processes. One of the most important aspects of skills development is to be able to identify stakeholders for a collaborative innovation properly.
<i>Skills</i>	Identify relevant examples at local level	4	"I take away many of the tools proposed in the course and a new look, perhaps a slightly more holistic look at the way processes can be interwoven. (OO_A)"
	Tools for SH engagement	9	"I remember with great pleasure the whole part of the mapping of needs, I think it is a very interesting instrument, because it addresses all the parts of society that interact in an exercise of collaborative innovation. (OO_B)"
	Interaction with other participants	8	We could not analyse and assess the creation of networks and lasting cooperative relationships after the training, but we were able to investigate the intentions and motivations. Participants appreciated and were interested in different viewpoints from the group, and some connections were formed, but actual plans to collaborate with other participants were not strong.
	Tools for QHC navigation	6	However, some participants did indicate an impact of the courses on new projects or initiatives.
<i>Intended change</i>	Develop skills for QHC	3	"We are hopefully starting a bigger project soon, where we start such processes, [and] it is definitely helpful to know which organisations are already there and to have talked to someone [in the course from such organisations]." (WK_E)
	Adaptation to participants' practice Networks	9	
	Adaptation to participants' life	7	
	New projects	5	
		4	

“This way of working of collaborative innovation can contribute a lot [to societal change].” (IC_I)

It was striking to see that the level of baseline knowledge, which varied considerably amongst the participants, influenced the impact of the courses on the acquisition of knowledge. However, regarding deep knowledge of collaborative innovation, several interviewees revealed more profound reflections about topics touched upon and triggered by discussions or content from the training programmes. Examples include inclusion, the roles of each helix, communication between helices, and how collaboration can be started. For instance,

“The question that I ask myself after such a meeting is: “Is there deliberate exclusion in such a concept and thus the lack of inclusion? Or is there simply too little information provided in such a project and thus the inclusion is missing? Well, that was very exciting and a bit philosophical.” (WK_D)

Our research is based on the realisation that a lack of practice or reference examples is usually perceived as a barrier for QHCs in innovation. Therefore, we went beyond exploring the knowledge of QHCs or collaborative innovation to focus on the new knowledge regarding practical experiences or cases. In this line, some participants mentioned that the courses allowed them to identify relevant examples at the local level. Although this part is quite challenging, as the courses were designed to occur in different countries and settings, the collective experience and a strategic selection of participants potentiate the link to specific contexts. This result indicates that it is essential to allow for exchange amongst local experiences, as coming from the participants themselves to compensate for the feeling that some cases, although interesting, lacked a real connection to the participants’ reality. As recommended by a participant in one workshop:

“It would have been interesting to know what the problems of the participants actually are, where you could connect with your own expertise or where you could actually need input for your own problems.” (WK_F)

The course participants also stress the importance of getting to know practice examples. In some cases, they indicate that the cases were the most useful part of the course. In others that they would have liked more practice examples or examples more relatable to the specific contexts.

“[I would have liked] More examples, to be able to better identify some of these methodologies during the course.” (IC_I)

The focus group conducted with trainers confirmed these findings: trainers had a strong impression that participants gained knowledge by attending the courses. The trainers did reflect on the fact that several of the participants had experience with related topics. Nevertheless, this did not hinder the unfolding of notably more deepened knowledge in the field. Through discussions with each other, participants gained new perspectives that may not only be based on their different backgrounds but also stem from their different levels of experience, which triggered a fruitful exchange, as mentioned by one of the trainers:

“Participants[...] realised these small things make a difference, for example the language that they speak [...] the language according to the helix is important, [one] that is not frightening. Other participants could gather this information from discussions with each other, not just [with] us, but in their conversations.” (Trainer #1)

Skills

Participants of the intensive course, which was the longest and most in-depth of all training programmes, referred to the new abilities to start, navigate, or push QHCs as having acquired the *“methodology for cooperative innovation itself”* (IC_J) and a new perspective for proposing projects to funding agencies. However, our results show that for all courses, one of the most important aspects of skills development identified by participants is properly identifying stakeholders for collaborative innovation. Most participants expressed their satisfaction with the new tools for stakeholder identification. They noted that these made them think more systematically, holistically, and inclusively. Also noteworthy is the use of online boards as a powerful tool for collaborative action.

“When requesting European projects, it is very important what they call stakeholder engagement, that then you can also communicate with all those agents that you think might be interested in your research [or innovation] (...) These methodologies [the ones covered in the course] will allow me to know how to focus on these projects, to keep this in mind and to incorporate it as far as possible.” (IC_I)

Regarding skills for interaction with others, throughout all training programmes, participants gained new contacts. They interacted with a range of different actors — both from similar fields of expertise but also from quite diverse professional backgrounds. One of the aims of bringing together different actors and stakeholders in the trainings was to foster networks of actors who might collaborate at a later stage and highlight the significance of involving actors hitherto not considered:

“I got the impression that there is a very exciting network of people who are interested in participation processes and also implement them, which we have not had on our radar so far.” (WK_E)

Whilst the trainers were not able to provide deeper insight into the development of skills of participants, their reflection in the focus group on the participants’ reactions and contributions confirmed the impression that participants perceived the activities conducted positively and were satisfied with the tools provided for concrete key aspects like stakeholder engagement. Several participants expressed interest in using the tools in the future:

“I also add that [the participants] came out of the course with a set of tools and resources that are very, very powerful (...) We were also happy to see that they are willing to use the course materials afterwards.” (Trainer #2)

Intended Change

The networking was especially important in the workshop and related to building further collaborative partnerships and sustainable connections across sectors and projects. Whilst we could not analyse and assess the creation of networks and lasting cooperative relationships after the training, we could investigate the intentions and motivations concerning keeping in touch with other participants and creating new networks and collaborative connections. Participants appreciated and were interested in different viewpoints from the group, but actual plans to collaborate with other participants were not strong. However, some connections were formed. For example, one participant was about to start a project and mentioned that some of the persons and organisations present at the workshop could be relevant for future cooperation.

“We are hopefully starting a bigger project soon, where we start such processes, [and] it is definitely helpful to know which organisations are already there and to have talked to someone [in the course from such organisations].”
(WK_E)

Another participant mentioned that some of the learnings gained during the training triggered some ideas and intentions in their personal surroundings and inspired a family member to start a citizen initiative:

“There is actually something [an impact] that’s not related to work, but more in private life, if you can say so when you are a citizen (...) There’s a plan about building a lot of new buildings in [my] area and a lot of people are very angry about that because the countryside used to be a very peaceful place. I talked to my father about it actually after this course, and he wrote out an email for all the citizens in the area calling for a meeting. They are right now actually planning this meeting! He is hosting a meeting for, I think, 30 people tomorrow about this case and about how to contact the commune.” (WK_H)

We found that the courses also encouraged some participants to continue their paths of applying participatory methods and inclusive setups in innovation and to tackle the barriers ahead of them with creative or holistic solutions.

“It is actually a confirmation of what we are doing and that we continue to do so. Because we actually do it exactly the same way; we start with stakeholder mapping and see what roles they play, and we then design a process and develop the methods for it.” (WK_C)

Moreover, two key impacts were mentioned: (1) useful tools and methods that participants plan to apply in upcoming projects (e.g. helicopter technique or materials used) and (2) new perspectives or questions to be asked during their research/projects relating to inclusiveness and setting up inclusive processes. As one of the interviewees mentioned:

“[the training on collaborative innovation] is an instrument that can be perfected, but that you have done very well and that is very useful. Actually, what I have to prepare [a project the participant is involved in] is online; I have

to talk to my colleagues to see how we do it [based on the experience of the course].” (IC_J)

The trainers’ perception in this regard was that participants were interested in the contacts they made during the courses and might use them in the future. However, trainers agreed that the courses could not provide an environment to foster future collaboration between all participants. This may partly be due to the online environment in which the courses occurred. However, trainers were already able to share several other impacts in the form of individual narratives of participants who reached out that relate to the adaptation to life and practice of participants.

“We had [...] two to three “accidental impacts”: [we] received an email from one of the participants who was motivated and inspired by the workshop to rethink her projects in her work field and also asked for advice on how to design [them] more participatory.” (Trainer #3)

In summary, our results show that knowledge takeaways amongst training participants were strong, as well as the acquisition of skills (although not as strong as knowledge). The takeaways in these two categories seem to depend strongly on participants’ previous experiences. Regarding the intention to change and the establishment of a network for collaborative innovation, we found that participants showed interest in each other and saw the benefit of having a diversity of people attending the training. However, the actual forming of connections was limited through the courses. There is a clear limitation to creating strong bonds between participants that will collectively act towards collaborative innovation when offering online training and bringing together many diverse stakeholders. Intention to change is hard to measure and can be speculative in this research. Nonetheless, we discovered several impact narratives during the interviews or follow-up communication with participants. This indicates that some participants plan on or apply elements derived from the training in their own professional or personal projects.

Discussion

Collaborative forms of innovation, like the one described by the Quadruple Helix model, are complex processes that require the interaction of diverse perspectives and actors (Carayannis & Campbell, 2009). The investigation of real-life QHCs shows that challenges to setting up these collaborations emerge at different levels (Braun et al., 2021a), which increases the risk of collaboration failures (García-Terán & Skoglund, 2019). These potential risks and challenges should be actively and continuously addressed throughout the innovation process. In this research, we approached one way to address these challenges via training of individuals, which has shown in other contexts to foster practical skills and deliberations that allow researchers and innovators to engage in new ways of working (Mejlgaard et al., 2019; Tokalić et al., 2021).

In this paper, we report a training intervention for actors from the Quadruple Helix that was expected to impact learning competencies required for QHCs in innovation. This intervention consisted of the design, implementation, and evaluation of three training programmes of different focus and length that aimed at smoothing out some of the main barriers that are commonly found in the progress of collaboration, as well as providing knowledge, tools, and strategies to work through some of the key aspects for managing collaborations across four sectors and maintaining them over time. As we expected, our results show that the courses allowed participants to explore aspects that facilitate or hinder such collaborations and provided tools, methodologies, and strategic guidelines to support the design, implementation, and evaluation of QHCs. The participants actively joined this kind of training as they were interested in continuing or setting up a QHC, which explains the openness towards inclusive innovation. Amongst our course participants, there was a lack of knowledge and awareness of QHC or other inclusive forms of innovation collaborations. The courses were highly suited for this population, which led to positive outcomes in terms of knowledge acquisition, skills development, and the intention of change. However, contrary to our expectations, this was not the case for participants with previous experience in QHCs, although the training did allow these participants to connect with others. Our training programmes can be potentially adapted to people with deep knowledge of collaborative innovation and the adjustments required will need to be identified with such a target population.

Other studies have identified key success aspects in real-life Quadruple Helix Collaborations for innovation. For instance, building institutional structure through formal procedures for partner selection, reporting, and communication is essential for effectively managing the knowledge and information transferred between ecosystem partners in other models as open innovation (Bacon et al., 2019). In that regard, the training programmes approached the concepts of stakeholder mapping and engagement. They provided practical tools and case examples of how this can be achieved in different settings. The participants indicated that this was one of the most important outcomes of the training programmes, indicating that there is still a need to acquire skills for — some could argue — basic processes. This is another reason why we find the QHC model adequate for collaborative innovation practice because it allows the collaborators to identify blind spots of the represented institutions through this kind of stakeholder mapping.

The courses also approached the importance of defining common goals, ensuring trust, and managing power differences (Bryson et al., 2006; Rabelo & Bernus, 2015; Starkbaum et al., 2021). Those issues might be perceived as subtle or secondary, yet our study suggests that practitioners identify them as a challenge frequently found in QHCs. We explicitly included these aspects in the training design, and the participants acknowledged that they required more detailed knowledge of empathy, communication, and power management to embark on collaborative innovation efforts.

The courses are also intended to provide a networking platform and create alliances with people and institutions with a shared interest in a particular societal issue or grand challenge. Due to COVID-19 restrictions and the need to accommodate the training to an online format, we expected serious difficulties to achieve the goal

of networking. Nevertheless, our results show that participants created a short-term network and general awareness of other actors in the field. Most connections were not very strong, so the networking impact needs to be explored in further research (i.e. there is still to be seen if the bonding between participants was taken up further) and strengthened in upcoming training efforts.

Concerning overcoming challenges in QHCs, we considered the three major levels of challenges identified in real-life collaborations that served as a theoretical basis for this study. Strikingly, the results show that our intervention positively influenced them to different degrees. The first level, the activity level, refers to the moments at which actors intending to open up their innovation process are confronted with questions relating to stakeholder engagement and involvement (Braun et al., 2021a). Since civil society is in itself quite diverse and includes a range of different actors and institutions, much thinking has to be devoted to who should and can be involved as a representative from this helix and in what ways (González-Martinez et al., 2021; Starkbaum et al., 2021). In that context, exercises such as stakeholder mapping and analysis can be very useful since it helps to structure the stakeholder involvement process analytically. Our courses focused on that aspect, and the results show that, as it was previously mentioned, both participants and trainers highlighted the acquisition of knowledge and tools for stakeholder identification as a crucial element.

The second level of QHC challenges is the governance level (Braun et al., 2021a; Popa et al., 2021). Research organisations, public services, and private companies are often well-funded and have highly professional staff, resources, and available infrastructure at hand. Civil society actors, on the other hand, often lack such resources and skills, which hinders their ability to contribute to innovation activities on equal footing (Starkbaum et al., 2021). We found that trainees gained new knowledge about the importance of involving civil society, power imbalances, and how to deal with different — and sometimes conflicting — interests. Participants not only gained knowledge, but also reported an intention to change their behaviour regarding these aspects.

The third level, the systemic level, is where framework conditions for both the practical activities and governance paradigms are determined, too often without systematically addressing the specific needs of civil society actors (Braun et al., 2021a). The central value of innovation is often framed in terms of economic profit, which can drive the development of new products, services, and technologies. However, it might not be the best incentive to open innovation to citizens (Arnkil et al., 2010). The courses approached aspects to overcome this level of challenges through common goal setting, holistic thinking, and critical reflection. As was reported by several participants in the interviews, the courses enabled them to get new perspectives, a more holistic view of the innovation process, and, most importantly, fostered critical thinking. It was also mentioned that the diverse profile of the course participants strengthened the critical reflection on the issues raised in the courses. In this regard, carefully selecting course participants to mimic a QHC is key to approaching this level of challenges.

Our findings showed that participants' composition could influence our training programmes' impact. This can be explained by the fact that two out of three competencies that allow individuals to engage in or create Responsible Innovation, as

described by Popa et al. (2021), are dependent on diversity. These competencies, system thinking and transdisciplinarity, are relevant pillars for setting Quadruple Helix Collaborations for innovation. The system thinking competence refers to the “ability to collectively analyse complex systems across different domains (society, environment, economy, etc.) and across different scales (local to global), thereby considering cascading effects, inertia, feedback loops, and other systemic features related to sustainability issues and sustainability problem-solving frameworks” (Wiek et al., 2011). On the other hand, the transdisciplinarity competence refers to the ability to “structure relations, spot issues and recognize the legitimacy of other viewpoints in (...) decision-making processes regarding environmental, social and economic issues, to involve all stakeholders and to maximise the exchange of ideas and learning across different groups (...) and different disciplines” (Lans et al., 2014). Having diverse views amongst the course participants allows a more holistic approach to the scenarios presented, encouraging the development of these two competencies and indirectly preparing participants for QHC contexts.

A more holistic approach to a particular innovation situation also highlights the importance of designing training as a space for reflection and deliberation. In this line, Mejlgaard et al. (2019) have analysed the impact of providing training in light of the Aristotelian concept of *phronesis*. *Phronesis* refers to the capacity to understand a certain context, assess a given situation, and weigh the options towards the best decision for the individual and society (Tassone et al., 2018). It emerges only with personal, practical experience as people encounter and reflect on multiple practical issues (Kristjánsson et al., 2021). The concept of *phronesis* highlights the importance of practical training, especially in fields such as collaborative innovation, which necessarily implies a break in the usual way of thinking and doing. This has been shown successfully in teaching Responsible Research and Innovation (RRI) practices. It has been recommended to teach RRI primarily as a practical skill where deliberation on real-life issues is rehearsed, preparing trainees for later encounters with such problems (Mejlgaard et al., 2019). Our courses used practical activities that encouraged deliberation, and the results show that this methodology helped participants to practise reflexivity by interpreting their context, identifying stakeholders, thinking, and deciding responsibly. In this context, too, ensuring a diversity of profiles amongst the participants is particularly important to achieve processes of profound reflection.

This study, and the training programmes related to it, gives innovation practitioners a framework and resources to acquire knowledge and develop skills that will most likely facilitate their work when dealing with QHCs and generally in collaborative innovation processes. Moreover, these results are helpful to policymakers responsible for or interested in promoting and supporting QHCs. For the later target, this study acknowledges the need to partner regulatory or funding schemes with training, directly impacting trainees’ knowledge, skills, and intention.

Research Limitations

The development, implementation, and evaluation of our training programmes showed positive outcomes that come with some limitations to consider. First, whilst the training programmes were developed closely in line with the applied research findings from five social labs in different countries, this was the only source from QHC real-life projects. As the literature on practical QHCs is still scarce, other resources and literature used to derive the content of the training programmes stemmed from related fields (e.g. stakeholder engagement, open innovation, multi-stakeholder partnerships) that may not fit the conditions of a QHC perfectly. We were aware of such limitations and actively tried to mitigate them through direct dialogue and participatory co-design with innovation practitioners, but this may bias the usability of the courses for different QHC contexts. The results discussed in this paper show that the content of our training programmes is helpful in a general context of collaborative innovation. However, they must most likely be refined according to further research findings on applied QHCs.

Secondly, though the implementation and communication of our training programmes was designed carefully, the number of participants attending them was limited, leading to a small sample size. Different cultural environments of the implementing organisations, as well as different contexts and course participant profiles, could affect the comparison across the five implementation activities. In addition, due to COVID-19 regulations, implementation activities had to be transferred to an online environment. This prohibited the in-person implementation of two training formats, the workshop and the intensive course. Consequently, not all activities could be implemented as planned, and thus, not all objectives could be equally addressed. We found that, although somewhat fielded with interactive online tools, particularly activities to achieve network-related goals fell short due to the nature of an online environment.

Thirdly, the results of the evaluation should be interpreted with caution. On the one hand, feedback from people who dropped out throughout the course was largely missing, though trainers tried to engage this specific group. This was particularly significant for the online course, with only a handful of people completing the course evaluation out of about 40 people starting the course. In addition, the selection of interviewees could represent a bias, as people willing to give interviews on their experience of the training programmes are more likely to lean positively towards the course and thus may be less likely to report negative feedback. In line with the nature of the qualitative investigation, only a few people could have their say about the courses. This means other participants, who may have additional impacts to report, remained unnoticed. Some impacts were discovered through participants who proactively contacted course organisers to tell them about their steps, but others may have been neglected. Moreover, due to the timing of the evaluation process, long-term impacts are still to be identified.

Conclusions, Implications, and Future Research

Our study fills a significant gap in existing research and practice with innovation practitioners and policymakers by testing and evaluating training to promote collaborative innovations. To the extent of our knowledge, this is the first time such an effort has been systematically analysed and reported. Moreover, our results support the idea that intervening at the individual level via training enables innovation agents to engage in QHCs, by increasing their knowledge or awareness of key aspects of such processes and acquiring tools to implement new ways of doing or changing their attitude.

We showed that the collaborative design and implementation of at least three different training programmes, even when implemented online, directly impact the participant's learning competencies, which could potentially impact their practice in the medium to long term. These impacts relate to the acquisition of knowledge and tools, the further use of the materials, the creation of new projects, or the change in mindset. Moreover, our analysis indicates that in providing training for QHC, at least two things are important: (i) to provide well-chosen, written, and worked-through case studies and course materials that connect to real-life problems and (ii) to select participants that add diversity to the group carefully and yet have similar baseline knowledge and expertise on the issue.

Managerial Implications

Our results respond to previous studies which have remarked on the necessity for continuous learning in collaborative efforts, both to transfer knowledge and to have a shared development of skills and competencies, and on the importance of training as a space for reflection and deliberation. This study serves innovation practitioners to identify relevant resources to acquire knowledge and develop skills that will most likely facilitate their work when dealing with QHCs or, more generally, collaborative innovation processes. Moreover, our results target policymakers responsible for or interested in promoting and supporting open innovation by acknowledging the need to partner regulatory or funding schemes with training.

It is important to stress that when investigating real-life QHCs, there is barely any QHC that genuinely involves the four helices continuously and democratically and barely any that has a broader representation of civil society. Also, in this study, civil society course participants mainly represented existing and structured organisations rather than being “random citizens” interested in a topic or a particular problem. This raises the question of whether further training programs should be designed or implemented that focus concretely on the setup of a QHC and guides the process of establishing such a collaboration. Our experience could inform such training but would most likely require an intensive and sustained effort, like a mentoring program. This reflection is again relevant for policymakers in their efforts to promote collaborative innovation processes.

Theoretical Implications

In the last decade, there has been significant theoretical advancement in understanding collaborative innovation dynamics and the benefits of involving civil society actors in innovation. However, there needs to be more investigation on the practical application of QHC theory. Our study responds to that need and makes available three training programmes designed to support Quadruple Helix Collaborations, structured with case studies based on actual experiences. The evaluation of these programmes, presented in our results, together with the analysis of their impact and limitations, provide a further understanding of the factors that may influence the implementation of QHCs in reality and become a tool to support practitioners in engaging in more collaborative and democratic forms of innovation.

Furthermore, our work established 13 categories of competencies to involve or promote QHC for innovation (Table 2). This sets a framework on a set pool of elements that are necessary for the establishment and navigation of successful QHCs in practice and provides a structure to take them into consideration when providing training.

Our work also contributes to the pedagogical literature regarding channels for developing transversal skills. The results from this study evidence some potential and limitations of online training. Although our training targets adults, it provides some structure into working dynamics for online teaching, which has been intensively studied in the last years due to the COVID-19 impact on education.

Ideas for Future Research

Future research and practice should implement and evaluate training programmes on a broader scale to draw larger evaluative sample sizes and comparability. Also, it would be essential to assess the face-to-face implementation of training programmes, to compare the differences in competencies and the impact that arise in such a context, as opposed to the online format. This will allow further exploration of the limitations and potentials of online training, which has been one subject of intense research after the COVID-19 pandemic. Follow-up on participants of the training programmes after significant time has passed would enable a deeper understanding of the long-term impact of the training programmes. In the coming years, the training programmes will need to be reviewed and adjusted in light of new research and literature on QHC practice and training needs as they become available. Finally, future work on the definition and understanding of real-life QHCs should continue to assess, in different contexts, if the competencies described in our paper are consistently crucial for the start, implementation, and successful navigation of such collaborative innovation processes. To the extent of our knowledge, this is the first time that training is used to understand and support collaborative innovation, and we expect that our work helps scholars, practitioners, and policymakers to get interested in this approach and continue to investigate it.

Author Contribution All authors contributed to the study conception and design. Material preparation, data collection, and analysis were performed by Luisa Barbosa, Magdalena Wailzer, Laura Soyer, and Gema Revuelta. Anna Gerhardus and Francisco González also contributed to data collection and analysis. Vincent Blok and Gema Revuelta contributed with deep revisions of the manuscript. The first draft of the manuscript was written by Luisa Barbosa and Magdalena Wailzer and all authors commented on previous versions of it. All authors read and approved the final manuscript. Conceptualisation: Luisa Barbosa and Gema Revuelta; methodology: Luisa Barbosa, Magdalena Wailzer, and Laura Soyer; formal analysis and investigation: Luisa Barbosa, Magdalena Wailzer, and Laura Soyer; writing — original draft preparation: Luisa Barbosa and Magdalena Wailzer; writing — review and editing: all authors, importantly Luisa Barbosa, Anna Gerhardus, and Gema Revuelta; supervision: Gema Revuelta.

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Data Availability The curricula, instructions and recommendations for each training course is openly available for download, modification and reuse at: <https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5e4d981c0&appId=PPGMS>. Moreover, research data used for the courses' evaluation and the analysis in this study are available upon request from the corresponding author.

Declarations

Conflict of Interest The authors have no competing financial or non-financial interests to declare that are relevant to the content of this article.

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