Co-producing Knowledge: Challenges of the Transdisciplinary Research in Pandemic Times

Maria Angelica Jung Marques, Eduardo Giugliani and Jane Lucia Silva Santos
Pontifical Catholic University of Rio Grande do Sul - PUCRS, Porto Alegre, Brazil
HFACTORS - Human Factors and Resilience Research Group
maria.angelica@pucrs.br
giugliani@pucrs.br
jane.santos@pucrs.br

Abstract: Human Factors is a broad area of interdisciplinary and transdisciplinary studies and research focused on the perspective of the interaction between organizational, group and individual factors that aims at improving the performance and safety of people in complex organizations and socio-technical environments. Knowledge to develop solutions to the complex problems that arise in this context can be co-produced by academic and non-academic actors through a transdisciplinary research framework that integrates the daily practices of stakeholders and creates structures that make co-production spaces effective for corporate's practices. This paper present and discuss the strategies and challenges for developing spaces for human factors-based knowledge co-production on a transdisciplinary research project during the pandemic period of COVID-19. This ongoing research was designed to develop interactions and to co-produce knowledge aimed at the safety culture of companies in the oil and gas sector. Under the imposition of social distance and its consequent challenges, strategies to promote interaction, iteration, sharing, integration, co-creation, and co-production of knowledge had to be redesigned. Based on partial results, the research discusses and analyze the main dilemmas for the knowledge coproduction focusing on the 30 researchers, and on the knowledge coproduction between researchers and stakeholders. Although the COVID-19 pandemic had imposed new forms of relationships, the main challenges remained on the integration of knowledge as perceived by the research team. This paper presents the confrontation of the knowledge co-production challenges imposed by the new context associated with addressing two new constructs for the oil and gas industry, human factors and resilience, to improve safety culture. The discussion suggests and presents possibilities to overcome these challenges to continuous stimulate co-production of knowledge in these organizational environments.

Keywords: co-producing knowledge; knowledge; transdisciplinary; industrial sector; human factors.

1. Introduction

Transdisciplinary research and knowledge co-production are by nature interactive and iterative processes of knowledge production used to address complex real-world problems. They require participants to have an ethic of openness, tolerance, and respect for different perspectives, and a commitment to mutual learning and mediation processes where conflicts and different values are negotiated when not fully resolved (Stokols 2006). Transdisciplinary projects usually demand that participants step out of their disciplinary "comfort zone" which leads, in most cases, to new conceptualizations about social and scientific phenomena transcending disciplinary boundaries (Klein 1996; Pohl, Klein, Hoffmann, Mitchell, & Fam 2021). In addition to the existence of spaces and mechanisms for collaborative action, since the act of engagement across domains and disciplines is as important as the production of knowledge itself (Marques 2020), the coproduction of knowledge is a process that includes a collaborative stage of problem structuring and trust building, through knowledge generation, to a stage of exploration of practical impacts (Harvey, Cochrane, & Van Epp 2019). Harvey et al. (2019) emphasize that co-production processes produce more than just knowledge, they develop capabilities, build networks, foster social capital, and implement actions that contribute to the issues at hand.

The pandemic of COVID-19 beginning in 2020, has presented challenges that directly impact how collaborative and co-productive actions are perceived and carried out, especially in interdisciplinary and transdisciplinary research projects. In Brazil, a transdisciplinary research project which aims to co-produce knowledge oriented to improve operational safety in the oil and gas (O&G) industry based on human factors and resilience, was initially conceived, and structured to develop its research activities face-to-face, with constant iteration and interaction between teams of researchers and workers from the O&G industry. This is a case of a project that had to adapt and reinvent its dynamics and its process of knowledge co-production, overcome barriers, and manage the unexpected. This article contributes to the debate about transdisciplinary knowledge co-production and (the creation of) co-production spaces, from the perspective of adaptability and management of the unexpected in the oil and gas organizations involved. Considering that existing theoretical and empirical studies on transdisciplinary knowledge co-production are predominantly focused on domains related to public

administration, education, environment, and climate change (Marques 2020), this study addresses a yet unexplored domain related to the context of industries in the O&G industries. In addition, this study covers a set of researchers from multiple disciplines, which increases the complexity of project management and the knowledge integration process. Furthermore, the main object of the project - Human Factors, by itself demands inter and transdisciplinary action to meet the objectives established with the O&G industries of the case in question. In this sense, the literature related to safety culture, associated with Human Factors in industry, does not include studies on application of research methodologies of transdisciplinary knowledge co-production for the resignification of operational safety practices.

Based on this context, the study seeks to answer what extent the transdisciplinary process is affected by the perception and experience of researchers in relation to the processes of transdisciplinary knowledge co-production. Therefore, it was considered the heterogeneous understandings of inter and transdisciplinary reflects on a diversity of practice and expectations across disciplines. Additionally, how the COVID-19 pandemic has affected the knowledge integration processes, and what is the effect of the strategies used to achieve the goal of transdisciplinary knowledge co-production.

This article presents and discusses some challenges, barriers, and strategies for knowledge co-production in a transdisciplinary research project during the pandemic period of COVID-19, based on partial results. The next section presents the concept of transdisciplinary and the relevance of knowledge co-production in inter- and transdisciplinary research projects, addressing the challenges posed by the COVID-19 pandemic to co-produce knowledge. The third section presents the context studied and the methodological approach employed to conduct the initial empirical study. In the fourth section, the main partial results are synthetically presented and discussed. In addition, in the last section, some final considerations and suggestions for future studies are pointed out.

2. Co-producing knowledge in the transdisciplinary research

The concept of transdisciplinary refers to different types of knowledge production for social change that are based not only on the integration of knowledge from different disciplines, but also on the inclusion of values, knowledge, know-how, and expertise from non-academic sources (Klein, Keestra, & Szostak 2010). The literature on transdisciplinary research presents a wide range of definitions (Boyd, Buizer, Schibeci, & Baudains 2015), and considers the complexity of an issue and its diverse perceptions about it, setting aside the idealized context of science to produce relevant knowledge from the input of various stakeholders (including interest groups from society, industry, and government). This means to say that, in practice, transdisciplinary research requires collaborative actions in iterative cycles (Lawrence 2015; von Wehrden et al. 2019). Transdisciplinary research, as well as knowledge co-production, are terms coined to refer to the processes of knowledge integration/connection between academic and non-academic actors that lead to the creation, communication, and use of combined knowledge (Bremer & Meisch 2017; Mauser et al. 2013). This iterative and interactive process of combining worldviews, experiences, and values with factual and scientific forms of knowledge leads to the generation of more comprehensive and inclusive understandings of a problem at hand. Some issues that underpin this process directly interfere in the success or failure of co-productive actions, such as trust, power and leadership, communication, governance, and engagement, among others (Marques, 2020). Trust, for instance is an important catalyst that allows passive information to be transformed into valuable knowledge (Qurniati, Febryano, & Zulfiani 2017). Communication in social relationships has also been widely recognized as a precondition for successful transdisciplinary projects (Tilo Weber 2018 - https://i2insights.org/2018/10/02/language-matters/).

Knowledge co-production has been an effective means of producing usable knowledge in science through a collaborative process between researchers (i.e., academics) and practitioners (i.e., decision makers). The growing field of research on knowledge co-production suggests that the strength of this approach is precisely the direct connection and collaboration between researchers and practitioners (whether policy makers or local resource managers) (Djenontin & Meadow 2018). Moreover, collaboration, inherent in the process of co-production, is a theme present in the literature on the subject since it refers to the act of engagement between domains and disciplines and is as important as the production of knowledge. Compared to disciplinary research processes, knowledge co-production extends from a collaborative stage of problem structuring and trust building through knowledge generation, to a stage of exploring the practical impacts of that process (Harvey et al. 2019).

The concepts of co-production, co-design, co-development, and co-evaluation belong to a family of collaborative terms (Bremer et al. 2019). Co-production is an iterative, interactive, and collaborative process that uses a diverse and plural set of knowledge sources (scientific and practical) to define and solve complex real-world problems (Armitage et al. 2011; Bojovic et al. 2021). In co-design, stakeholders and researchers work in a coordinated and integrated manner to establish a common understanding of the research and co-production goals and agree on the roles that different groups have in moving toward the research goals (Mauser et al. 2013). In co-production, a continuous exchange between researchers and stakeholders takes place, with scientific integration through inter- and transdisciplinary interfaces to ensure consistency of the research process and address questions about the uncertainty of the results (Mauser et al. 2013). Integration is an effective way to ensure that disciplinary research questions stem from the overall needs of the project and then researched by the respective discipline to then transcend in the transdisciplinary process where stakeholders and researchers dialogue to ensure the interaction of their respective knowledge (Bammer 2013, 2019; Bammer et al. 2020; Hoffmann 2016).

Although co-production processes are described as iterative, there is no single approach to implementing successful co-production actions (Brix, Krogstrup, & Mortensen 2020). Furthermore, research on co-production indicates that there is still no widely accepted understanding of what the term co-production means in practice (Bremer et al. 2019; Norström et al. 2020). A co-production space, for example, can be understood as "a complex meeting place where several different academic traditions and practices converge, overlap, affect each other, conflict, or cooperate to describe and effect co-production" (Bremer and Meisch 2017, p. 20). In this regard, beyond the conceptual discussion on knowledge co-production, there are pragmatic and solution-oriented research approaches (Hoffmann, Thompson, & Pohl, 2019; Jacobi et al. 2020; Popa, Guillermin, & Dedeurwaerdere 2015; Schneider et al 2021) that have given rise to laboratory and experimental environments for research with and for society in diverse fields, such as: business and innovation (e.g., Baccarne et al. 2014), urban development (Bulkeley et al. 2019), environmental policy and sustainability (Bergmann et al. 2021; Schäpke et al. 2018), among others. In addition to integrating scientific and practical knowledge, these approaches seek to turn co-produced knowledge into action, supporting practical transformation through learning.

The relevance of knowledge co-production, especially in complex contexts and problems, is unquestionable. However, there are still many challenges and points of attention to enable the experiential learning process in co-production spaces. Theoretical mediation and the establishment of bonds of trust among participants, for example, are fundamental to the unfolding of co-creation and co-production activities. Asymmetric forces and powers, as well as values, beliefs, and language can become barriers to knowledge co-production (Laursen, Gonnerman and Crowley 2021), also ethical and gender issues, academic tribalism (corporatism), etc. (Baptista et al. 2020). The pandemic of COVID-19, according to the World Health Organization (WHO), has changed the way life is conducted, and the resulting social legacy has brought about more social changes (World Health Organisation 2020), which even affect how research projects are developed. People and organizations have relied on digital media to cope with these changes in their daily activities, especially when it comes to digital communication. To reduce interpersonal interactions and respect social distance, contactless services have in many cases become "the new normal" (Ratten 2020). Whether face-to-face or not, transdisciplinary knowledge co-production is expected to integrate scientific and non-academic disciplinary knowledge into a transdisciplinary research framework for solving complex problems.

3. Study context and method

Transdisciplinary, interactive, and participatory research approaches are often suggested as appropriate means to meet both the requirements posed by real-world problems and the goals of science (Hoffmann, Pohl, and Hering 2017; von Wehrden et al. 2019). In this article we put the lens on a specific study context, i.e., a 36-month inter- and transdisciplinary research project (ITD Project) that - faced with the advent of the COVID-19 pandemic shortly after its initial months of research activities - needed to deal with the imposition of social distance and its consequent challenges, and to generate spaces and strategies to promote the co-production of techno-scientific knowledge. The ITD Project is developed by a multidisciplinary team of about 30 research scholars from various disciplines and research fields (including HSS - Humanities and Social Sciences; and STEM - science, technology, engineering, and mathematics) and counts on the direct involvement of five companies from the O&G industry that operate with the common goal of O&G exploration and production off the Brazilian coast. Once the project was conceived to be developed from collaborative interaction actions with companies in a face-

to-face format, the first major challenge was to manage the unexpected with the immediate adaptation of its research methods and the entire structure of communication and relationships for execution in the digital format. In this scenario, the process of co-production of knowledge, designed to be developed face-to-face, needed to be rethought and adapted, and the implicit dilemmas and challenges usually present in interdisciplinary and transdisciplinary research projects have become increasingly frequent and explicit.

To face the imposed challenges of knowledge co-production, the ITD Project employs two central constructs, namely: Human Factors and Resilience. To strengthen the safety culture, especially in offshore operations (O&G exploration and production units), the multidisciplinary team of researchers of the ITD Project seeks to develop jointly with the companies, tools, methods, and technologies based on concepts and principles of human factors and resilience. The set of actions are centered on three perspectives: (a) Applied Research; (b) Experimental Development; and (c) Practical Implementation. This means that new knowledge will be generated while experimental and practical application activities will be developed in the case study's operations. The project uses the expanded concept of transdisciplinarity defined by Jahn et al. (2012, p. 4) and proposed by Hoffman et al. (2019), where transdisciplinary research is a reflective approach that encompasses interdisciplinary collaboration among academics, added to collaboration among stakeholders concerned with a particular real-world problem, in processes of mutual learning and knowledge integration. Considering the proposed actions, centered on experimental development and practical implementation, it is sought that the various stakeholders participate in the identification and selection of results, and in the transdisciplinary knowledge co-production.

3.1 Initial empirical study

To better understand the studied context and the challenges related to the knowledge co-production in a transdisciplinary research project, some methodological procedures were implemented to conduct an initial empirical study with the team of researcher-academics of the ITD Project.

The study, still in progress, sought to raise qualitative data through semi-structured interviews, and quantitative data through an online questionnaire (survey via e-mail) using as response options a 5-point Likert scale of agreement (1- strongly disagree, 2-disagree, 3-non-disagree nor agree, 4-agree, 5- strongly agree). The guide script for the semi-structured interviews was based on the results of SHAPE-ID: Shaping Interdisciplinary Practices in Europe, which aims to establish a comprehensive knowledge base covering the different understandings of interdisciplinary and transdisciplinary research (IDR and TDR), the factors that inhibit or support them, and a set of success criteria for integrating the Arts, Humanities and Social Sciences and other disciplines, Science, Technology, Engineering, Mathematics and Medicine, into ITD research practices to solve real societal problems. The questions in the questionnaire consist of statements from the literature and previous studies on knowledge co-production, Marques (2020), SHAPE-ID (Baptista et al. 2020), Robledo and Hoffmann (2021). The questionnaire link was sent to all members of the multidisciplinary research team of the ITD Project, specifically its researcher-academics. By December 2021, 27 responses to the questionnaire have been obtained and 12 interviews with researchers have been conducted (another 10 are planned to take place later in 2022). The preliminary results of this study are presented below.

4. Presentation and discussion of results: initial study

The results presented below, still partial, instigate some reflections. It should be kept in mind that all questions were answered during the pandemic considering the conditions imposed by it since March 2020. The analyses also rely on extensive material collected during interactive meetings between researchers and companies during two years of the ITD Project.

Considering inter and transdisciplinary co-production in practice, this study sought to understand the perception of the team regarding these practices, evaluating frequency, collaboration, engagement, communication, knowledge integration, among other aspects. From the answers to the questionnaire, the following are some preliminary results organized into three macro-categories: (i) researcher's actions/experiences and choice/preferences, (ii) nature and characteristics of ID projects (general), and (iii) nature and characteristics of ITD projects (integration), the latter about the integration process in ITD projects, according to the perception of the researchers participating in this study.

About the researcher's actions/experiences and choice/preferences (Figure 1), one of the results that draw attention concerns the frequency with which researchers collaboratively produce interdisciplinary scientific work. When presented with the statement "I frequently participate in the collaborative production of scientific

work", 63% agreed with the statement, however, 55% agreed that the priority of production is related to their field of research. These issues also appear in the interviews, when the researchers explained that they see the importance of producing more interdisciplinary scientific work, but the concentration of activities of scientific production and participation in research networks is still quite concentrated within their disciplinary field. On the other hand, when working on an interdisciplinary project, 30% of the respondents stated that they prefer to "collaborate with researchers with whom they already work or have worked", but 34% said they had no such preference.
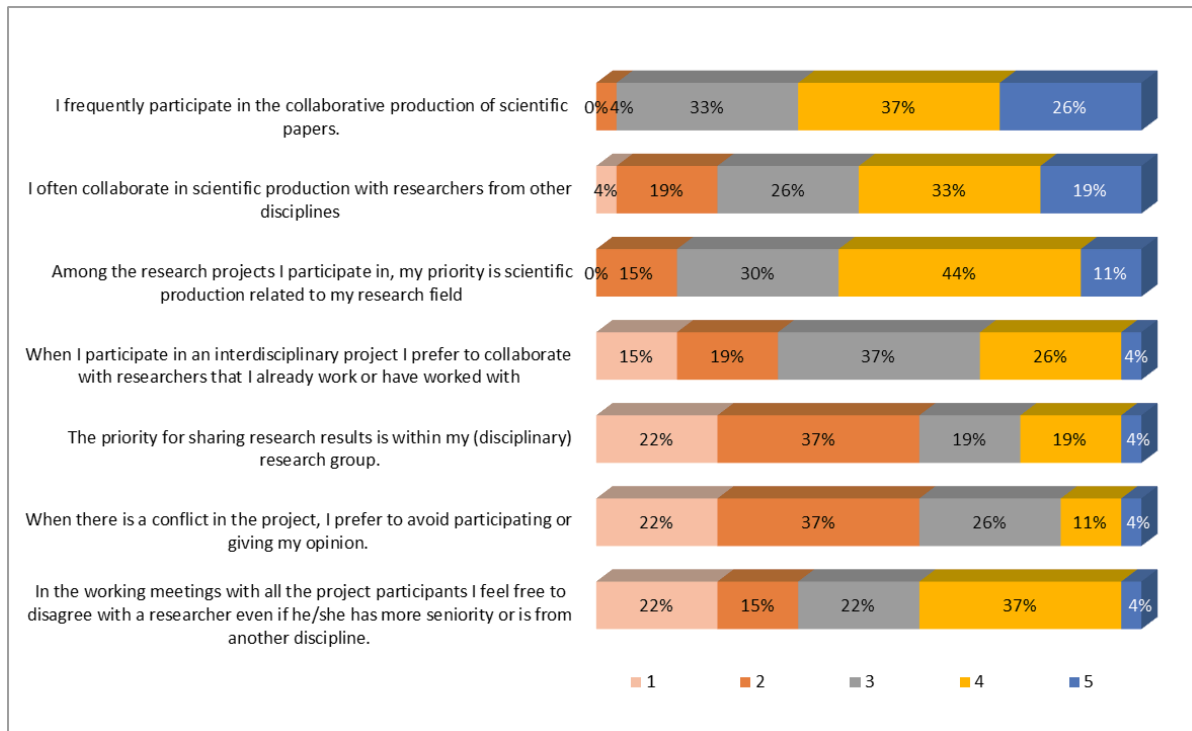

Figure 1: Researcher's actions/experiences and choice/preferences

Source: Elaborated by the authors

About the nature and characteristics of ITD projects in general (Figure 2), one can see that the questions/statements related to themes A (engagement, motivation, and dedication), C (coordination and sharing) and E (communication and interaction between teams / in planned spaces) are those that obtained the highest scores, all between 78% and 100% of partial or complete agreement (responses predominantly between 4 and 5). Another aspect that draws attention concerns autonomy (in thematic block B, representation, and autonomy of the disciplines - Figure 2).

When asked about the knowledge integration processes (Figure 3), an essential activity of the co-production process, 85% of the researchers agree that this integration happens during all phases of the project. However, 60% agree with the statement "integration requires specific skills" and 48% neither agree nor disagree with the statement "integration requires previous experience".
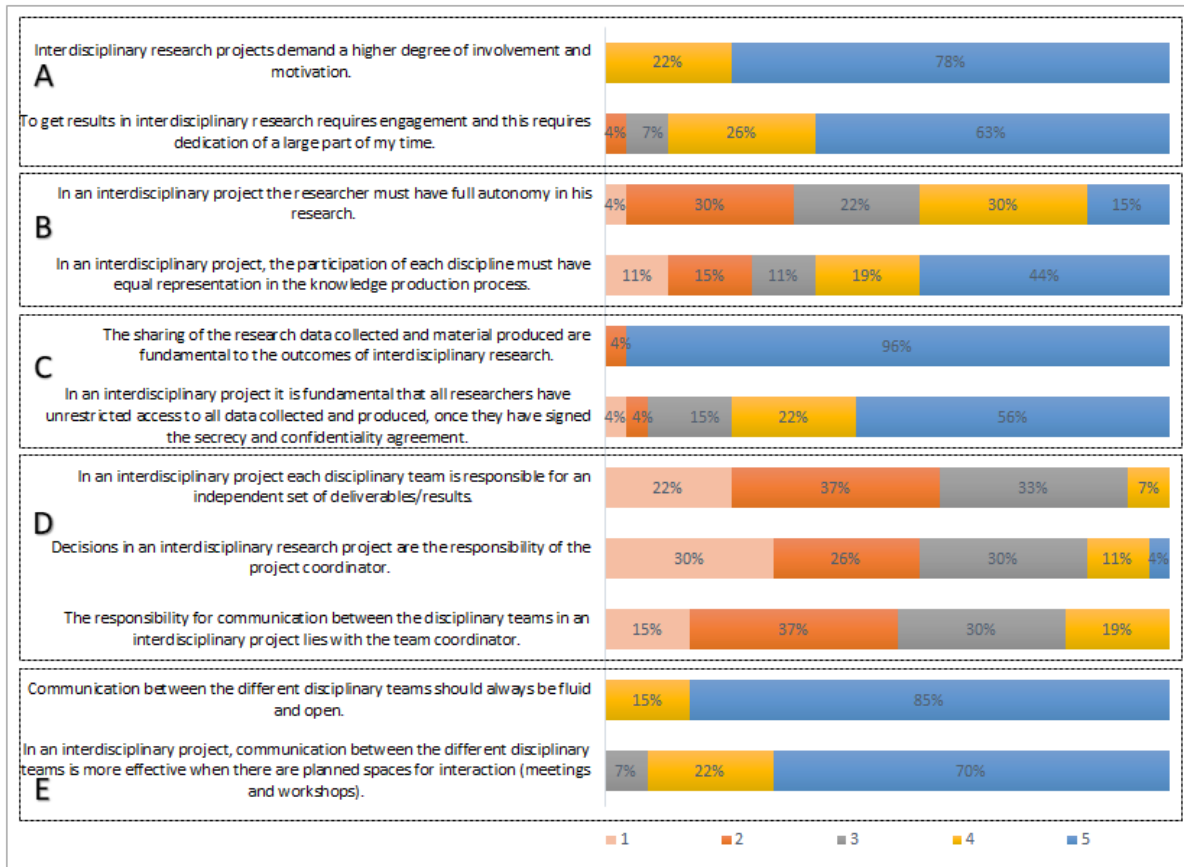
Figure 2: Nature and characteristics of ID projects (general) according to the perception of the study respondents, sorted by thematic blocks

Note: % from 27 answers. Thematic blocks of questions: A = Engagement, motivation and dedication, B = Representation and autonomy of disciplines, C = Coordination and Sharing, D = Roles and responsibilities, E = Communication and interaction (between teams / in planned spaces).
Source: Elaborated by the authors
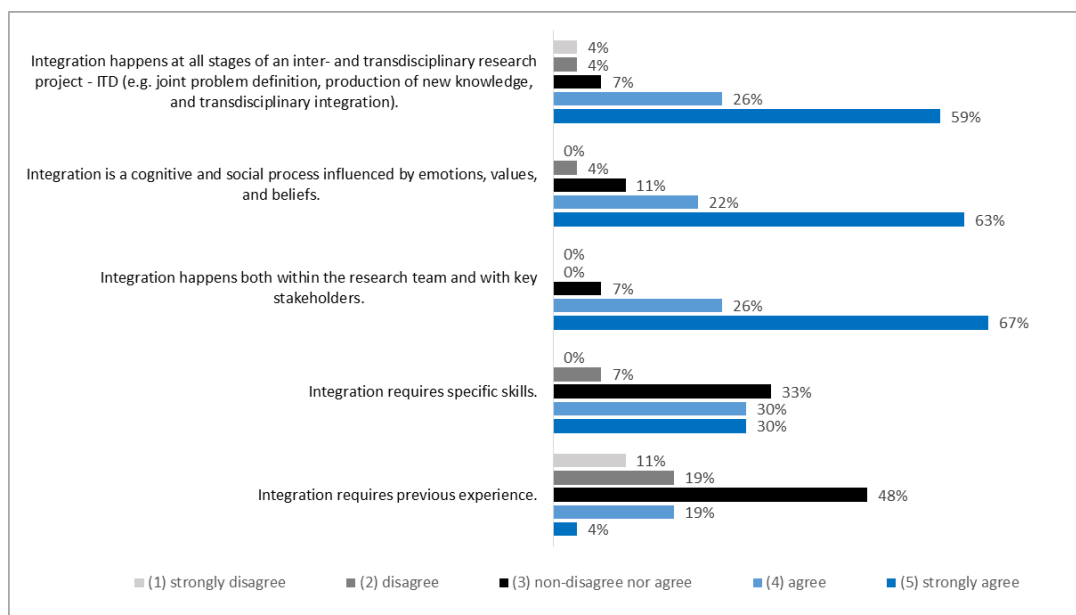
Figure 3: Knowledge integration on ITD projects according to the perception of survey respondents
Source: Elaborated by the authors

Respondents were asked to rank order the five potential barriers to inter- and transdisciplinary collaboration. Through their responses, the top barriers are listed in descending order in Table 1.

Table 1: Main barriers to inter- and transdisciplinary collaboration

Main barriers	% of answers
Cognitive and/or epistemological differences among partner researchers	14.63
Academic tribalism (corporatism)	13.01
Division of scientific work (each one does their part independently)	12.20
Lack of knowledge about their discipline (by those who are not from the area)	11.38
Lack of motivation of researchers to do interdisciplinary research	8.94
Power differences among the participants	8.94

Source: Elaborated by the authors

As evidenced in table 1, in addition to the cognitive and/or epistemological differences between the partner researchers as the most frequent barrier, academic tribalism, the fragmented way of working (each one does their part and then joins the parts), the lack of knowledge about disciplines different from their own, as well as issues related to the motivation for interdisciplinary work and the power differences between the participants stood out. These barriers also match the responses to the other questions such as the statement presented earlier in Figure 1: "when I participate in an interdisciplinary project I prefer to collaborate with researchers with whom I already work or have worked" with 37% neither disagreeing nor agreeing and 30% generally or completely agreeing.

In general, the researchers, when asked about the barriers to working collaboratively, although they claim to have adapted well to remote work (even seeing several advantages in it), still perceive the difficulty of understanding and making themselves understood, especially in the relationship between HSS and STEM areas.

Among the strategies developed, the creation of multi-level co-production spaces in the form of interdisciplinary working groups stands out. This strategy allowed attacking some of the sensitive points identified at the beginning of the pandemic that are directly related to the themes A (engagement, motivation, and dedication), C (coordination and sharing) and E (communication and interaction between teams / in planned spaces), which obtained the highest scores.

These multi-level co-production spaces have allowed for expanded participation of researchers who previously depended on their disciplinary group leaders to participate in technical-scientific debates. This has increased motivation and engagement while dissipating power structures, increasing the sharing of information and knowledge. The formation of the WGs also facilitated knowledge integration processes, which as shown in the results, demands learning beyond specific competencies unknown to most participants.

5. Concluding remarks

The partial results presented on the co-production of transdisciplinary knowledge, point to some initial reflections. The project has a lot of researchers from various disciplines and areas, both in HSS and STEM, which increases the complexity of relations in terms of cognitive and epistemological differences, requiring coordination, communication, and engagement in multiple instances. In addition, it has a diversity of participating companies, different cultures, pandemic context, which required creativity and adaptations to meet the challenge of social distance.

By creating spaces of co-production with shared leadership, in addition to the sharing of information and knowledge, it was possible to advance the integration of knowledge, the improvement of trust relationships, and the dissipation of traditional power structures. Furthermore, the partial analysis of the researchers' perspectives on the understanding, purpose, and practice of inter- and transdisciplinary collaborative actions, demonstrates the unawareness and fear of some of the researchers when it needs to in fact integrate knowledge in collaboration with another discipline. This integration is not something natural, although it is perceived as very important, demanding great cognitive effort. Many testimonials report the initial difficulty of relating at a distance and the need to "reinvent" oneself, and, although they see positives in distance interaction, most miss face-to-face interaction, especially for insight into non-verbal communication, and to "disarm" potential barriers of cognitive or epistemological misunderstanding.

By discussing some divergences and points in common, we present some paths and demonstrate theoretical advances in understanding how coproduction of knowledge is understood, as well as the practical utility in offering co-productive spaces to help navigate this new reality. It is worth mentioning, however, that one of the limitations of this study is that the perception of the participants of the companies has not yet been incorporated to a greater extent, although qualitative data from meetings and gatherings have subsidized the analyses so far. As next steps in the research, it is planned to expand the number of interviews with professionals/workers of the companies, where we intend to explore the perception of the stakeholders, their understanding about it, their motivations, and their engagement in the co-production process. The literature still does little to explore stakeholder engagement and given the field of application of the research it is even less explored (O&G sector).

Moreover, future studies could focus on the identification and analysis of the strategies and mechanisms that facilitate/promote the knowledge co-production in inter and transdisciplinary research projects, as well as on the processes of knowledge integration that permeate the spaces of knowledge co-production.

Acknowledgments

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