# A Transdisciplinary Research Model Through Knowledge Co-Production in Complex Sociotechnical Systems

**Eduardo Giugliani, Maria Angélica Jung Marques and Priscila Susin**
PUCRS, Porto Alegre, Brazil

giugliani@pucrs.br
angelicajmarques@gmail.com
pri.qsusin@gmail.com

**Abstract:** This paper presents the transdisciplinary research and conceptual model adopted by the projects developed within the research center HFACTORS – Human Factors and Resilience Research Center. Transdisciplinary research produces knowledge with workers, be they leaders or sharp-end professionals, and within the company, as it seeks to understand the daily demands without imposing pre-defined solutions. In this sense, a transdisciplinary research model aims to integrate and co-produce "actionable knowledge" to face challenges and complex problems where disciplines alone are no longer enough. This paper shows how the HFACTORS Center seeks to implement a multi-perspective approach to its interventions, transcending disciplinary boundaries, co-producing knowledge, and connecting scientific knowledge with everyday practice. Such an approach requires multiple ways of working, developing strategies, and creating tools and spaces for co-production where different teams can work and interact. Interaction can occur on various levels and allows both the co-creation and co-production of narratives, solutions, and negotiations, as well as the prototyping of ideas and learning from integrating knowledge (scientific and applied). Therefore, we present the HFACTORS research model, describing the strategies and mechanisms used to develop processes of transdisciplinary knowledge co-production aligned with a Human Factors perspective, its implementation challenges and future research opportunities.

**Keywords**: Transdisciplinary research, Knowledge co-production, Research model, Complex sociotechnical systems, Resilient systems

## 1. Introduction

The Human Factors area presents itself as a broad field of studies and research with transdisciplinary nature. It is centered on the interaction between organizational, group and individual factors with a view to improving people's performance in organizations and complex socio-technical environments. It is a comprehensive field of knowledge, with multiple domains and objects. Among the challenges in this field, transdisciplinary research stands out.

Transdisciplinary research aims to co-produce knowledge and integrate it into the daily practices of stakeholders, with the building of structures that make these practices more effective for corporate action and change. These arrangements point, in turn, to opportunities and challenges for governance and innovative processes in organizational environments: spaces for prototyping, experimentation and validation, among others (Engels, Wentland, Pfotenhauer 2019). Transdisciplinary research takes a comprehensive, multi-perspective approach, problem- and solution-oriented that transcends disciplinary boundaries and promotes the connection between science and practice (Pohl 2011). In addition, transdisciplinary research proposes a reflective approach of interdisciplinary collaboration between academic and non-academic stakeholders (Bammer et al. 2020; Hoffmann, Thompson, Pohl 2019).

When dealing with topics typical from the Human Factors research area such as safety in complex socio-technical systems, the association between human elements, complex structures, high technology, finite resources, knowledge (specialized and tacit), variability and uncertainties, transdisciplinary research is essential. In this sense, new tools, methods, and methodologies are needed to facilitate the processes of integration and co-production of knowledge. In this article, we offer the HFACTORS view on the co-production of transdisciplinary knowledge in the field of Human Factors, as well as the conceptual model adopted.

The HFactors is a Research Center formed by an interdisciplinary team of researchers, involving specialists from the Pontifical Catholic University of Rio Grande do Sul (PUCRS, Brazil) and partner universities, in areas such as Resilience Engineering, Sociology, Social Work, Psychology, Engineering, Media and Knowledge Management. The Center focuses on design and carries out R,D&I (research, development and innovation) projects with high added value and intensive technical-scientific knowledge, involving models and technologies aimed at strengthening the culture of safety, resilience and human factors. Concepts and definitions about transdisciplinary research are presented in this paper, as well as key notions on the co-production of knowledge, pointing out how the HFACTORS seeks to implement a broader, multiperspective approach to its projects,

oriented towards problems and solutions that transcend disciplinary boundaries, and proposing a connection between science and everyday practice (Pohl 2011).

## 2. Transdisciplinary Research and Knowledge Co-Production

Transdisciplinary research and knowledge co-production are terms coined to refer to processes of knowledge connection between academic and non-academic actors that lead to the creation, communication, and use of combined forms of knowledge (Bremer, Meisch 2017; Mauser et al. 2013). Knowledge co-production has been an effective means of producing usable knowledge in science through a collaborative process between scientists and decision makers (Djenontin, Meadow 2018). This has led researchers and professionals to turn to knowledge co-production as a promising approach for advancing studies in complex environments (Norström et al. 2020): co-production emerges as a response to complexity, oriented by context, problem-focused, demanding the participation of various disciplines and non-academic actors in the process - not just as informants, but as interested and active parties, which includes negotiation and agreement on research questions and activities (Jacobi et al. 2020).

Bammer (Bammer 2019; Bammer et al. 2020) highlights that specialization in the integration and implementation of research is an essential but often overlooked component in the context of addressing complex problems. It is through knowledge integration that "actionable" knowledge is co-produced. Actionable knowledge is that knowledge that can be worked on and applied to solve a real-world problem. The co-production of actionable knowledge requires researchers to adopt ways of working together that create time and space to build teams, networks, relationships, narratives, and prototype ideas, to fail, learn, and start over (Evans, Terhorst, Kang 2017)

Although transdisciplinary research is a recognized approach to dealing with complex real-world problems, some aspects can limit its success. Schmidt et al. (2020), for example, warn about the importance of stakeholder involvement, a central aspect of transdisciplinarity, which still lacks more broad reflection on its objectives in the literature. In this sense, with a view to integrating different perspectives and bodies of knowledge to develop scientifically valid and relevant results for companies, the transdisciplinary research approach allows reflecting and respecting the diversity of epistemologies, cultures, roles, and interests of all parties involved (Hoffmann, Thompson, Pohl 2019; Jahn, Bergmann, Keil 2012; Schmidt, Falk, Siegmund-Schultze 2020).

In this sense, a preponderantly influencing factor of the transdisciplinary research process is the ability to promote the integration of knowledge, either through tools, dynamics, and strategies. In this direction, there is a rich body of literature dedicated to this process, for example, Klein (2012), Hoffmann et al. (2017); Hoffmann (2016); Bammer (2013), Pohl et al. (2021), Pennington (2016), Defila and Di (2015), Marques, Giugliani e Santos (2022), to name a few. The HFACTORS Model seeks to add to this literature on the experience of co-production of transdisciplinary knowledge oriented to problems in complex socio-technical systems with a focus on the Human Factors field. The model's approaches and strategies developed by the HFACTORS team in recent years are presented below as well as the challenges to consolidate such model.

## 3. HFACTORS Model of Transdisciplinary Research and Knowledge Co-Production

Through transdisciplinary research, the HFACTORS seeks a comprehensive, multi-perspective, problem- and solution-oriented approach that transcends disciplinary boundaries, proposing a "bridge" between science and practice (Pohl 2011). The insights of Polk (2014) and the interaction model proposed by Hoffman et al. (2019), in which different forms of knowledge from science and practice combine and relate to each other to produce a "third" sphere of knowledge, served as inspiration for the HFACTORS model of transdisciplinary research in complex socio-technical systems. This model is illustrated in figure 1.

The HFACTORS model aims to establish cyclical processes of thematic synthesis and co-production of knowledge, in order to identify and overcome the challenges that arise at different stages of a transdisciplinary research project, seeking to co-produce solutions to a complex problem. The establishment of the central problem, object of a transdisciplinary research, is based on a cycle of interactions with the team of the contracting organization, where the main research questions are co-designed (co-design stage). This cycle is based on practices from real world experiences and demands a series of interactions between academic and non-academic teams. Once the research questions are co-designed, the strategies and macro activities to be developed are elaborated. These macro activities, in turn, are developed in iterative and interactive cycles of co-design, co-production and co-evaluation, where knowledge is gradually integrated.

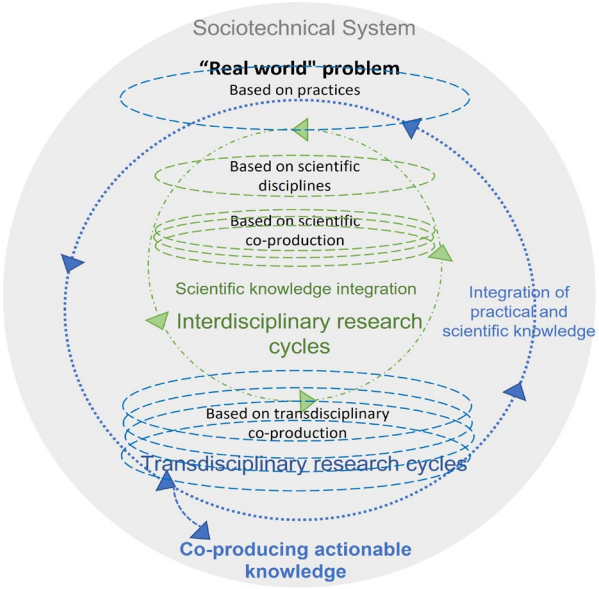


**Figure 1: HFACTORS Model – Conceptual Model of the Transdisciplinary Research Process In Complex Sociotechnical Systems**

In the HFACTORS, the proposition of knowledge co-production tools was based on a multilevel perspective, considering, at least, the following elements: a) the socialization of researchers around the reality and the language used in the socio-technical system that is object of the research ; b) the construction of a relatively common language in order to develop and share research results based on co-production; c) a relatively shared vision about the problem and object of research; and, d) the work in small interdisciplinary groups for the integration of knowledge, leaving the discipline-based production for the co-production of actionable knowledge. It is worth clarifying the strategies adopted by HFACTORS for each of these levels.

According to Thompson (2009), interdisciplinary research teams need to negotiate meanings and work continuously to establish and sustain what the author has termed "a sense of collective communication competence". The construction of linguistic 'bridges' within the HFACTORS, for example, occurred from two demands.

The first concerned the researchers' ability to dialogue and understand the realities presented by the workers of the socio-technical systems under analysis, considering the collection of data from very different methods. The construction of research instruments and the contextualized analysis of results requires, therefore, a massive approximation between researchers and the routines and dynamics of the systems. The proposition of formal spaces of exchange between researchers and professionals from different areas of the contracting organizations, especially through workshops, seminars, and lectures, is one of the first actions in terms of conceptual adjustment. This includes the recognition of technical terms and jargon, without which it would not be possible to interpret much of the data collected.

Another opportunity for language alignment, and perhaps the most important, was the possibility for the research teams to experience the routine of the sectors being investigated, in person whenever possible, such as, for example, in the oil industry, embarking on offshore oil and gas exploration and production platforms, or even in onshore environments. In addition to a better conceptual harmonization, these experiences also make it possible to experience and observe what, from the workers' reports, would still be a purely theoretical abstraction of the research teams.

The second demand in terms of language is the need to build a relatively common conceptual and epistemological field between the different disciplines involved in exploratory research, in order to develop and share increasingly integrated research results. This challenge is especially complex, as it requires not only the co-creation of opportunities for dialogue, but also the effort between researchers from disciplines historically and supposedly positioned in so-called antagonistic positions. The conduction of common readings, the establishment of dialogues, seminars to share theories, concepts, and approaches, are key strategies adopted with the creation of an interdisciplinary scientific committee, also responsible for creating these spaces of exchange and integration of knowledge.

Another strategy adopted by the HFACTORS is the incorporation of a systemic look at the establishment of the research object and problem. As Moraes (2001: 34) points out, systemic thinking allows "the understanding of the different connections, the interactions that express the set of relationships established between the whole and the parts, between actions and feedbacks, making explicit, including the organization that shapes the system". For the implementation of transdisciplinary projects, incorporating a systemic approach means considering different perspectives and problematizations about the same socio-technical system during the process of exploratory research and during the cycles of co-production, admitting that all the answers could be right or wrong, depending on the point of view of the analysis and the observer (O'Rourke et al. 2019).

Finally, working in small groups or subgroups for integration and co-production of knowledge is also essential for effective praxis within the HFACTORS. They can be considered both a tool and a space for co-production but require a set of skills of collective communication and shared language, the capacity for a systemic look and, crucially, the horizontalization of disciplinary relations towards transdisciplinary work. As pointed out by Thompson (2009), these work groups provide some fundamental practices for co-production processes, among them, the sharing of time among researchers, the exchange of information about tasks, and the continuous negotiation in relation to language differences.

In the HFACTORS, the working groups are constituted from a long learning process, which begins in a disciplinary manner, especially during its first phases. However, in this process, they become increasingly interdisciplinary, as the cycles of knowledge integration develop from the formation of subgroups composed of researchers from different areas. As these cycles are repeated, each group assumes different thematic fields. The segmentation by area, in this way, becomes more diffuse, especially due to the need for transdisciplinary articulation directed towards practical problems of the socio-technical systems investigated, which need to be contemplated in their final phase of action-research.

This integration of knowledge is increasingly and constantly challenged as transdisciplinary research cycles are developed, with the active participation of professionals from the contracted organization. To this end, one of the strategies adopted by HFACTORS was the creation of spaces of co-production of knowledge where issues related to work practices are problematized and negotiated from the foundations and principles of human factors. Finally, another important strategy developed by HFACTORS is the construction and availability of virtual spaces for knowledge sharing and dissemination, which aim to stimulate constant interaction and co-production among academic and non-academic members of the project, such as the digital platform HFACTORS.

## 4. Final Remarks

The authors developed this article with the main objective of presenting the HFACTORS research model. Based on its focus on action and on a Human Factors approach, we can list two basic constructs for its effective performance: transdisciplinary research and knowledge co-production. Since 2014 the HFACTORS Center's team has engaged with applied transdisciplinary research. Based on these experiences, the model aims to advance in a propositional way toward solving problems in complex sociotechnical systems. It is also worth mentioning the resilient capacity developed by HFACTORS throughout its trajectory (learn-respond-monitor-anticipate), offering answers and solutions to complex problems within the transdisciplinary context that surrounds us, as well as the requirements for transformation imposed by the 21st century.

## References

Bammer, Gabriele. (2019) "Key issues in co-creation with stakeholders when research problems are complex", Evidence and Policy, Vol 15, No 3, pp. 423–435.

Bammer, Gabriele et al. (2020) "Expertise in research integration and implementation for tackling complex problems: when is it needed, where can it be found and how can it be strengthened?", Palgrave Communications, Vol 6, No 1.

Bammer, Gabriele (2013) "Disciplining interdisciplinarity: Integration and implementation sciences for researching complex real-world problems", ANU Press.

Bremer, Scott and Meisch, Simon. (2017) "Co-production in climate change research: reviewing different perspectives", WIREs Clim Change 2017, Vol 8, No 482, pp. 1–22.

Defila, Rico; DI, Antonietta (2015) "Integrating knowledge: Challenges raised by the '"Inventory of Synthesis"'. Futures, Vol 65, pp. 123–135.

Djenontin, Ida Nadia S. and Meadow, Alison M. (2018) "The art of co-production of knowledge in environmental sciences and management: lessons from international practice", Environmental Management, April.

Engels, Franziska; Wentland, Alexander and Pfotenhauer, Sebastian M. (2019|) "Testing future societies? Developing a framework for test beds and living labs as instruments of innovation governance", Research Policy, Vol 48, No 9, pp. 103826.

Evans, Katherine J.; Terhorst, Andrew and Kang, Byeong Ho (2017) “From Data to Decisions: Helping Crop Producers Build Their Actionable Knowledge”, Critical Reviews in Plant Sciences, Vol 36, No 2, pp. 71–88.

Hoffmann, Sabine; Thompson, Julie and Pohl, Christian. (2019) “Linking transdisciplinary research projects with science and practice at large: Introducing insights from knowledge utilization”. Environmental Science and Policy, Vol 102, April, pp. 36–42.

Hoffmann, Sabine, Pohl, Christian and Hering, Janet G. (2017) “Methods and procedures of transdisciplinary knowledge integration: Empirical insights from four thematic synthesis processes”, Ecology and Society, Vol 22, No 1.

Hoffmann, Sabine. (2016) “Transdisciplinary Knowledge Integration within Large Research Programs”, Gaia, Vol 25, No 3, pp. 201–203.

Jacobi, J. et al. (2020) “Utilization of research knowledge in sustainable development pathways: Insights from a transdisciplinary research-for-development programme”, Environmental Science and Policy, Vol 103, October, pp. 21–29.

Jahn, Thomas; Bergmann, Matthias and Keil, Florian. (2012) “Transdisciplinarity: Between mainstreaming and marginalization”, Ecological Economics, Vol 79, pp. 1–10.

Klein, Julie Thompson (2012) “Humanities, culture, and interdisciplinarity: The changing American academy”, State University of New York Press.

Marques, Maria Angelica Jung; Giugliani, Eduardo and Lucia Silva Santos, Jane. (2022) "Co-producing knowledge: challenges of the transdisciplinary research in pandemic times." European Conference on Knowledge Management. Vol. 23. No. 1.

Mauser, Wolfram et al. (2013) “Transdisciplinary global change research: The co-creation of knowledge for sustainability”, Current Opinion in Environmental Sustainability, Vol 5, No 3–4, pp. 420–431.

Moraes, Maria Cândida. (2001) Sistêmico. In: Fazenda, Ivani (Org.). Dicionário em Construção: Interdisciplinaridade, São Paulo, Cortez Editora.

Norström, Albert V. et al. (2020) “Principles for knowledge co-production in sustainability research”, Nature Sustainability, Vol 3, No 3, pp. 182–190.

O’Rourke, Michael et al. (2019) Disciplinary diversity in teams: integrative approaches from unidisciplinarity to transdisciplinarity. In: Strategies for Team Science Success. Springer, Cham, pp. 21-46.

Pennington, Deana (2016) “A conceptual model for knowledge integration in interdisciplinary teams: orchestrating individual learning and group processes”, Journal of Environmental Studies and Sciences, Vol 6, No 2, pp. 300–312.

Pohl, Christian. (2011) “What is progress in transdisciplinary research?”, Futures, Vol 43, No 6, pp. 618–626.

Pohl, Christian et al. (2021) “Conceptualising transdisciplinary integration as a multidimensional interactive process”, Environmental Science and Policy, Vol 118, No April, pp. 18–26.

Polk, Merritt. (2014) “Achieving the promise of transdisciplinarity: a critical exploration of the relationship between transdisciplinary research and societal problem solving”, Sustainability Science, Vol 9, pp. 439–451.

Schmidt, Laura; Falk, Thomas and Siegmund-Schultze, Marianna. (2020) “The Objectives of Stakeholder Involvement in Transdisciplinary Research. A Conceptual Framework for a Reflective and Reflexive Practise”, Ecological Economics, Vol 176, No June, pp. 106751.

Thompson, Jessica Leigh. (2009) “Building Collective Communication Competence in Interdisciplinary Research Teams”, Journal of Applied Communication Research, Vol 37, No 3, pp. 278-297.