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– Final report –

“Future pathways for TD research in international contexts: Integrating experiences on digital simulation tools, scaling, transfer and replication”

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Research topic

Transdisciplinary (TD) research faces inherent complexities due to its focus on addressing societal challenges through the integration of diverse knowledge systems. In our globally interconnected world, differences in values, norms, and decision-making processes create both opportunities and challenges for fostering learning and generating impact across different contexts (Bernert et al., 2023; Pärli et al., 2024; Tolksdorf et al., 2024). TD projects operate within highly specific socio-political and institutional infrastructures (Bojórquez-Tapia et al., 2021). By transferring or replicating initiatives in new contexts, existing knowledge can be leveraged to improve efficiency and accelerate progress toward sustainability transformations (Wiek et al., 2016; Wiek et al., 2018; Lam et al., 2020). This endeavour highlights the need for networks of TD-hubs able to enhance adaptive, context-sensitive approaches that integrate conflict resolution, stakeholder facilitation, and communication strategies. Despite growing recognition of amplification approaches, there remains a critical gap in developing international TD-hubs that parallelly support transformations in both the Global North and South.

To attend this need, this tdAcademy's project sought to explore the potential pathway towards establishing a set of local hubs (in this case: one in Mexico), by embedding decision-making frameworks into North-South partnerships. The project focused on exchanging digital and institutional infrastructure to create collaborative environments that foster knowledge co-production, deliberation, skill development, and continuous learning (Gómez-Priego and Bojórquez-Tapia, 2023). This project was guided by two research questions:

1. How can impacts from TD research be amplified through structured documentation and exchange as well as transfer and replication, and which supporting (infra-) structures are needed?
2. How can knowledge transfer practices and tools be embedded into capacity-building programmes to foster amplification processes?

The objectives were exchanging ideas and experiences on innovative approaches to integrating virtual and real elements in TD research projects, with a focus on utilizing "decision-visualization environments," and advancing the impact of TD research projects by promoting structured documentation, replication, and transfer to facilitate cross-case learning in international contexts, with a particular emphasis on experiences in the Global South. Thus, three key research areas were explored: (1) integrating digital tools into decision-

making processes, (2) designing TD-hubs for international networking, and (3) embedding knowledge transfer practices into capacity-building programmes. Aligned with tdAcademy's Topic Line 3 - *Contextual Dependencies, emphasizing adaptive, context-sensitive approaches*, this project enhanced networking and intercultural communication by exchanging experiences, expertise, and initiatives from TD processes in the Global South (Merino-Benítez et al., 2024).

Activities and outputs

Integrating digital tools into decision-making processes

Two activities were carried out with ITAS colleagues from the research group *Designing Real-World Laboratory Research*: (1) demonstrative visit, and (2) training workshop. The purpose was exchanging on infrastructure for decision-visualization environments that foster TD research, as well as brainstorming on case studies for its collaborative implementation. These activities allowed exploring how TD initiatives can be integrated into technological infrastructures; and visualizing interactive applications that could enhance inter-contextual stakeholder engagement and foster learning for sustainability transformations.

1. **Demo visit to Sustainable Futures Lab**. 24.02.2025.

This activity took place in ZEISS Innovation Hub, KIT Campus North, Karlsruhe. Participants included one ITAS colleague, and two form UNAM, including myself. The activity included a guided tour and a demonstration of the SFL and other advanced technological tools arranged to create immersive environments for multi-stakeholder experiences (Figure 1). These environments are designed to facilitate embodied rationality (Manheim and Spackman, 2022) for analytical deliberation, collaborative decision-making, and participatory scenario modelling. I had the opportunity to explore how these technologies enhance geospatial visualization, improve communication, and support more informed decision-making processes in complex contexts.

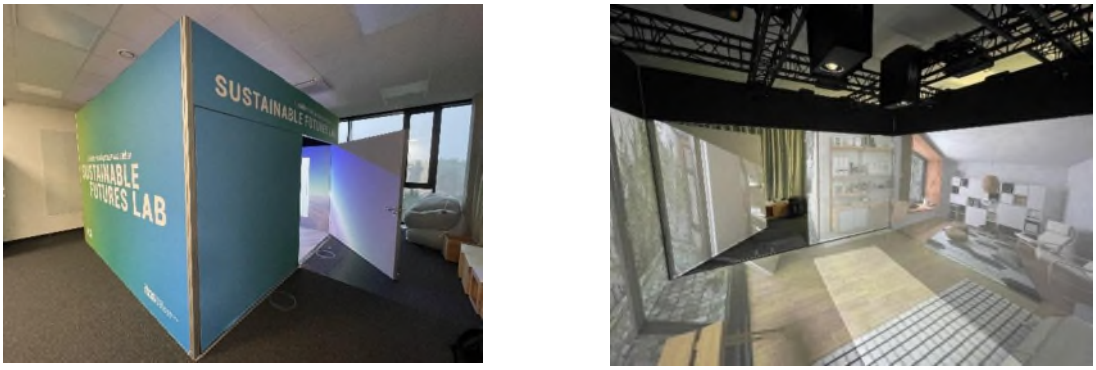

Figure 1 Visit and demonstration of the SFL insfrastructure.

2. **Training workshop on Mixed Reality-Glasses**. 25.02.2025

This activity took place in K9, ITAS, Karlsruhe. Participants included three ITAS colleagues, and two UNAM colleague, including myself. This activity featured an in-depth explanation of the technology and its functionality in creating expanded reality experiences**.** I was able to engaged in hands-on exercises and interactive games designed to explore the Mixed Reality-Glasses' potential for facilitating remote collaboration, enhancing engagement with stakeholders from different locations, and co-designing immersive environments (Figure 2). I explored how expanded reality can be leveraged to foster more dynamic interactions, improve collective decision-making, and support innovative problem-solving in complex, multi-objective contexts.

Figure 2 Training workshop on Mixed Reality-Glasses.

Designing TD-hubs for international networking

Two activities were carried out for sharing experiences from TD initiatives implemented in Mexico and identifying potential areas for international collaboration: (1) guest talk, and (2) workshop.

1. **Guest talk.** 26.02.2025.

This activity took place at ITAS, Karlsruhe, and online. Around 20 people attended this talk, both in person and online, including colleagues from UNAM, CIRET, University of Freiburg, and ITAS (from the research groups *Sustainable Bioeconomy*, *Research for Sustainable*, *Energy Technologies*, and *Designing Real-World Laboratory Research*), among others.

I gave a presentation on how analytical tools can integrate subjective perspectives from diverse knowledge systems into transdisciplinary frameworks that foster sustainability and

environmental justice (Figure 3). I explained two examples with indigenous communities in Mexico, where I applied multi-criteria decision analysis and exploratory modelling methodologies to bridge the gap between technical-scientific knowledge and local knowledge, ensuring that these traditionally marginalized communities are transparently incorporated into policymaking. This discussion underscored (1) the importance of analytical tools in participatory approaches for addressing complex socio-environmental challenges, and (2) how research can go beyond the isolated confines of academia to actively address real-world challenges in the Global South, where it is crucial to engage with the legal mandates embedded in both environmental conflicts and planning efforts.

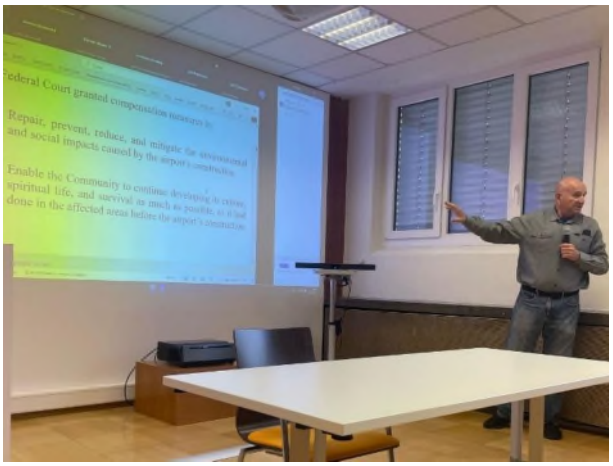

Figure 3 Guest talk.

This activity was announced on the tdAcademy webpage: https://td-academy.org/en/events-archiv/guest-talk-objective-treatment-of-the-subjective-transdisciplinary-engagements-in-the-global-south/

2. **Workshop on Infrastructure for TD research.** 26.02.2025.

This activity took place at ITAS, Karlsruhe. Participants included six colleagues form the research group *Designing Real-World Laboratory Research*, ITAS, two colleagues from the group *Transformational Sustainability Science*, University of Freiburg, and two colleagues group from LANCIS, UNAM, including myself. The focus of this activity was to exchange on the potentials of setting up a small world-wide set of “hubs” to facilitate a systematized knowledge exchange. Accordingly, the workshop aimed at establishing a shared understanding of the infrastructure necessary to support the effective collaboration of the TD research groups that work in different international contexts (Figure 4). Through presentations, discussions, and collaborative brainstorming, we:

Explored existing and potential infrastructure solutions, including the database.

Identified key needs, challenges, and opportunities for leveraging infrastructure to enhance Hub functionality.

Facilitated cross-institutional collaboration by aligning goals, resources, and expertise.

Defined actionable next steps for strengthening the research infrastructure and Hubs' network.

Figure 4 Workshop on infrastructure for TD research.

Workshop agenda:

Time	Activity
14:30-14:50	Welcome and introduction to the workshop. Recapitulation on the current infrastructure and potential use case of Karlsruhe. The objective was to establish a shared understanding of the workshop's goals, vision, and the broader context of both the use of the current infrastructure as means of collaboration and cross-case learning, ensuring alignment among participants from the outset.
14:50- 15:40	Set of small presentations about related infrastructure (20 + 5 min discussion each) 1. Mexico's digital apps and potential case studies: Presentation of potential digital infrastructure to implement in the SFL and future collaboration. 2. Database and cross-case analysis: Presentation of goal and vision, current status and next steps. Discussion on potential needs and uses.
15:40-15:50	Coffee break
15:50-16:35	Brainstorm on infrastructure for collaboration (using Miroboard for notes) addressing the following topics: Collaboration means/pathways What infrastructure is needed for TD processes in different contexts and countries? Are there specific use cases? Digital infrastructure How can existing databases inform the structure and functionality of the new platform? What resources can each institute contribute with? How can the new database be designed to remain relevant, accessible, and widely used over time? Amplification and replication How can we foster synergies for long-term development? How can ongoing projects contribute to the shared database? How can this platform support mutual learning, both within and beyond the core institutions?
16:35-17:30	Closure: Discuss tasks to take away and potential commitments. Agree upon next steps and share final thoughts.

The workshop concluded with a collective reflection on short-term commitments and key interests. The agreed next steps and products were the following:

Data Contribution: Each hub (U-FR, UNAM, ITAS) will have internal work for systematically report on around 15 cases, within 3 months.

Schedule regular meetings to keep sharing internal content and current practices, as well as progress on the database.

Data Expansion (GRIST): Continue adding more cases based on the agreed framework.

Collaboratively write a paper on hubs and common practices for amplifying processes across contexts.

Embedding knowledge transfer practices into capacity-building programmes

One activity was carried out, on February 28th, to deepen conversations from the workshop, focusing on capacity building for TD research in different contexts. This activity referred to a meeting with Katja Brundiers, from the research group *Transformational Sustainability Science*, University of Freiburg, Tatiana Merino and myself, from LANCIS, UNAM. During this meeting, we engaged in discussions about the contextual factors that enable or hinder capacities for sustainability at UNAM. These conversations built on ongoing efforts to institutionalize Transdisciplinary Interface Managers (TIM) by developing training programs and learning materials aimed at strengthening the competencies needed for scaling and amplification TD processes.

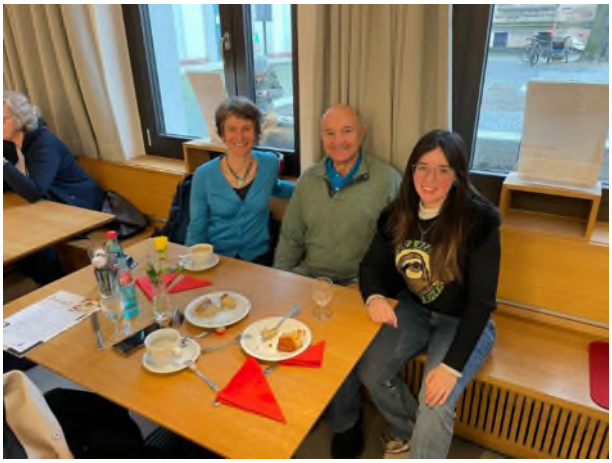

Figure 5 Meeting on capacity building.

The agreements of this meeting were the following:

Kick-off of the TIM training program could start in July 2025.

Efforts at UNAM could start as a summer school for students from the Sustainability Science PhD and Master's programs, first with national students with the goal of further connecting to international efforts, materials and trainers.

A series of videos will be made capturing testimonies on experiences where TIMs were crucial for a TD project or research to succeed.

Findings and insights

The activities and discussions I took part of underscored that structured documentation and exchange are critical to amplifying the impacts of TD research. Establishing a well-designed, collaborative database—populated with a broad range of real-world cases—was identified as a foundational step. This infrastructure would enable systematic knowledge transfer by making methodologies, lessons learned, and success stories visible and accessible across contexts. To ensure transferability and potential replication, it is essential to develop common vocabularies, classification categories, and digital platforms, co-created and iteratively refined by participating institutions.

In light of global experiences, these efforts resonate strongly with the notion of transformative partnerships as described by Riedy et al. (2025), which emphasize the interplay of inner capacities (e.g., openness, reflexivity, and trust-building), relational practices, and systemic goals. The work also aligns with the phases of partnership co-evolution—connecting, cohering, and catalyzing—which highlight the need to nurture relationships and shared intentions over time.

Moreover, drawing on the typology proposed by Withycombe et al. (2016), the emerging collaboration among institutions, such as UNAM, UFR, ITAS, could benefit from pursuing more intensive forms of international research and teaching collaborations. For instance:

Joint research on similar problems (Type 4) allows institutions to co-produce knowledge around shared challenges—such as urban sustainability, water governance, or climate adaptation—while contextualizing solutions.

Joint teaching initiatives with traveling students or faculty (Teaching Type 3 or 4) can develop cross-cultural competencies among future change agents and reinforce mutual learning through experiential engagement (e.g., summer school for TIMs training).

A critical pathway to address these international efforts would be embedding knowledge transfer tools into capacity-building programs for TIMs. These programs should enable experts in TD to adapt and apply sustainability insights in diverse settings. These forms of collaboration can accelerate institutional learning and elevate the relevance of locally grounded TD initiatives to global sustainability discourses. At the same time, they enhance the capacity to co-design and scale solution options that are both context-sensitive and

informed by broader systemic insights. Ultimately, the co-evolution of documentation systems, shared platforms, and training mechanisms represents a promising pathway for both scaling the transformative potential of TD research and establishing hubs as transformative partnerships capable of fostering deep collaboration and sustaining collective action across diverse contexts.

Outlook

The network of transdisciplinary hubs that we are developing aligns with other global initiatives (such as, Global Climate Hub, UN Sustainable Development Solutions Network, Regional Hubs for Sustainability Strategies, and Science Missions for Sustainability). This networks also align with the early stages of transformative partnerships described by Riedy et al. (2025): preparing/entering (developing self-awareness and readiness for collaboration), connecting/relating (building trust and epistemological openness), and cohering/integrating (identifying shared goals and cultivating relational reflexivity). By consciously engaging in these phases, the Laboratorio Nacional de Ciencias de la Sostenibilidad (LANCIS), UNAM, holds potential not only for institutional transformation but also for contributing to broader transformation systems—networks of people, projects, and programs that collectively advance sustainability goals.

To build on this momentum, I recommend the following actions for the tdAcademy community and other potential TD hubs:

1. **Deliberate Sensemaking and Peer Learning**
   Engage in structured reflection processes and collaborative learning across hubs to deepen understanding of shared challenges, evolving roles, and emerging best practices.
2. **Embed Monitoring, Evaluation, and Learning Mechanisms**
   Adopt adaptive frameworks that can both capture progress and support iteration. Recognizing, as Riedy et al. (2025) emphasize, that effective partnerships are dynamic—cycling through phases of emergence, deepening, and renewal—is essential for long-term impact.
3. **Promote Strategic Knowledge Infrastructure Development**
   Prioritize the co-evolution of documentation systems, shared platforms, and training mechanisms as a strategy for amplifying and replicating the reach and transformative potential of TD research. This infrastructure will not only strengthen local capacities but also enable more equitable knowledge exchange within global partnerships.
4. **Develop Decision Analytics Capacities**

Institutionalize TIMs and teams of TIMs within TD-hubs that possess strong analytical capabilities to address complex sustainability challenges involving multiple, and often conflicting, stakeholder demands. These TD-hubs should be designed to generate action-guiding knowledge (Grunwald, 2007) by leveraging advanced, AI-driven digital and data infrastructures (Koundouri et al., 2024). This includes the development and application of cutting-edge modeling approaches that support collaborative decision-making and enable systemic analysis of sustainability pathways.

To operationalize these recommendations, the following activities will be followed as concrete next steps:

Collaborative publication on transdisciplinary hubs and the design of collaborative infrastructures for sustainability research and learning.
LANCIS participation in the TRANSFORMS Conference, contributing insights on institutionalization, interface management, and multi-hub collaboration.
Production of a capacity-building video, highlighting the role and function of TIMs and showcasing real-world applications.
Organization of a national summer school at UNAM to officially launch the TIMs training program, designed as a space for knowledge co-production and practical skill development.
Development of joint proposals for international funding opportunities, leveraging the synergies across institutions to support long-term research and educational collaborations.

Together, these actions will not only reinforce the foundations of the td-hubs initiative but also position it as a strategic node within an emerging global network of transformative partnerships—accelerating both institutional change and systemic sustainability transitions.

Miscellaneous

Although brief, my stay at ITAS was truly inspiring and has sparked new efforts at LANCIS to advance transdisciplinary research. In particular, it has initiated our exploration of stakeholder engagement through augmented reality technologies and the development of Real-World Labs in Mexico. I gratefully acknowledge the tdAcademy for their financial support, which enabled my participation in this initiative. I thank Prof. Dr. Daniel Lang, his research group, and the Institute for Technology Assessment and Systems Analysis for their warm welcome and opportunity for meaningful international collaboration.

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