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The challenging role of researchers coping with tensions, dilemmas and paradoxes in transdisciplinary settings

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Abstract

Transdisciplinary learning is a response to address the comprehensive sustainability competencies for implementing the 17 sustainability goals of the Agenda 2030. Transdisciplinary contexts include socially distributed knowledge beyond scientific boundaries. This impacts the whole design process and specific tasks and roles of the researchers. Addressing the questions, "Which typical tensions, dilemmas and paradoxes need to be faced by researches in transdisciplinary settings?", and "How does the role of the researchers change and goes beyond traditional research settings when operating in transdisciplinary settings surrounded by tensions, dilemmas and paradoxes?", answers will be provided following existing analytical frameworks of transdisciplinary research design. Based on own experiences with and including observations of transdisciplinary settings at academia, transdisciplinary research and lecture settings will be analysed and compared by transdisciplinary criteria. Results show, in transdisciplinary settings, researchers or lecturers are more engaged with addressing poly-contextuality, the consciousness of the innovation paradoxes and the side-effects of ongoing interdependences. They take up multiple roles and have to deal with role ambiguity. Transdisciplinary lecture settings are even more demanding as they also have to meet the mentor role or maintain the students' learning progress.

KEYWORDS
dilemmas, paradoxes, poly-contextuality, tensions, transdisciplinary research design principles

1 | INTRODUCTION

Transdisciplinarity is a reflexive, integrative, method-driven scientific principle aiming at the solution or transition of societal problems and concurrently of related scientific problems by differentiating and integrating knowledge from various scientific and societal bodies of knowledge (Lang et al., 2012). Transdisciplinary research processes empower fast problem identification and problem structuring, allow direct problem solving in cooperation as well as between science and practice and permit the direct integration in research contexts (Gibbons et al., 1994; Jahn et al., 2012). Hence, in transdisciplinary contexts knowledge needs to be generated meeting the complexity of today's problems and includes socially distributed knowledge beyond scientific boundaries as well. So, transdisciplinary learning is among others capable to address the Agenda 2030 and the Education for Sustainable Development (ESD) stressing sustainability competencies for implementing the 17 sustainability goals, including systemic, inter- and transdisciplinary competencies (UNESCO, 2017). Bulten et al., (2021) identified three main tensions arising from transdisciplinary settings: "(a) researchers' self-perception and expectations; (b) expectations from transdisciplinary partners, funders and researchers' home institutions; and (c) societal convictions about what scientific knowledge is and how

it should be developed". Next to tensions, dilemmas and paradoxes also occur in transdisciplinary settings having impact, for example, on problem definition and knowledge creation. Vermeulen and Witjes (2020) emphasise the structures of societal problems, like complexity, persistency, wickedness, and the diversity of problem perceptions. However, "from sustainability transitions research, we know that the (simple) scaling up of an alternative may conflict with the evolutionary nature of societal change" (Augenstein et al., 2020). In fact, addressing sustainability real-world problems, the acquisition of ESD competencies and the joint work on practice-related problems and questions by scientists and practitioners or stakeholders face role- and task-related trade-offs, paradoxes and conflicts as well. Obviously, fulfilling diverse activities and roles as researchers in sustainability science is part of transdisciplinary settings, for example, change agent, knowledge broker, process facilitator, reflective and self-reflexive scientist (Wittmayer & Schäpke, 2014). Researchers even have to fulfil additional roles and activities when conducting transdisciplinary teaching together with students in transdisciplinary research contexts. So, the article addresses the following research questions: Which typical tensions, dilemmas and paradoxes need to be faced by researches in transdisciplinary settings. And, how does the role of the researchers change and goes beyond traditional research settings when operating in transdisciplinary settings surrounded by tensions, dilemmas and paradoxes?

2 | TRANSDISCIPLINARY RESEARCH APPROACHES IN SUSTAINABILITY SCIENCE

Transdisciplinary research approaches gain in popularity, have a wide range and are challenging. Transdisciplinary cooperation refers to socially relevant problems, initiates joint learning processes between scientists and non-university actors and aims at generating knowledge that is solution-oriented, socially robust and transferable to both science and social contexts or practice (Lang et al., 2012). There are several and different transdisciplinary approaches (well aggregated in Vermeulen & Witjes, 2020). There are various transdisciplinary research designs for executing transdisciplinary settings (Witjes & Vermeulen, 2020). A main focus is set on transdisciplinary research, mainly conducted in institutes or projects formats aiming at transformation. However, Pennington et al., (2013) state: "Transformative learning theory highlights three key stages that lead to radical change: a disorienting dilemma, critical reflection, and reflective discourse." Organising and creating conditions, where these three key stages take place, is the pivotal job of the researchers in transdisciplinary settings. These three stages take place in the main phases of transdisciplinary research stressed by Tejada et al., (2019). The authors focus on four pivotal characteristics of transdisciplinary research: (a) "real-world problems", (b) "integration of various disciplines and actors", (c) "cooperation and mutual learning of all actors involved", and (d) "production of scientific and other societal knowledge relevant for sustainable development", also see Table 1.

Pivotal transdisciplinary design principles and main activities were compiled in Table 1 based on selective existing analytical frameworks on transdisciplinary design (see Tejada et al., 2019; Luthe, 2017; Pennington et al., 2013; and Lang et al., 2012). The researchers have different activities and roles, like change agent, knowledge broker, process facilitator, reflective and self-reflexive scientist (Wittmayer & Schäpke, 2014), and face different challenges throughout the single phases stressed in Table 1. Activities and roles also change throughout the whole transdisciplinary process. So, the stages and the pivotal characteristics of transdisciplinary research provided in Table 1 shall also operate as a framework for further analysis on tensions, dilemmas and paradoxes that researchers have to deal with in transdisciplinary settings throughout the whole process. Therefore, in the further analysis it will be distinguished between transdisciplinary research and lecture settings as roles become even more challenging when transdisciplinarity is practiced in teaching settings. Two reasons are obvious: Researches have to deal with the role of the lecture in addition. Students represent more or less an additional stakeholder group in the sense of less experienced researchers and are facing multiple learning processes, like the transdisciplinary, methodological and content-based one.

From the researcher's side the transdisciplinary approach to teaching implementation needs to be considered (Alonge et al., 2016). The authors (Alonge et al., 2016) highlight three steps (a) organising for content development (a multidisciplinary teaching team and key course content), (b) content development (framework and learning objectives as well as course content in terms of specialisation), and (c) content delivery (pedagogical methods [also see McGregor, 2017] and testing). These steps are not fully integrated and become not obvious in the phases and criteria for transdisciplinary design in Table 1. Yet, as transdisciplinary teaching is part of transdisciplinary settings, these special features of transdisciplinary teaching should be considered and reflected separately in terms of tensions, dilemmas and paradoxes when researchers also step into the role of a lecturer. Facing Bulten et al., (2021) identified tensions transdisciplinary researchers in the role of a lecturer also have to consider (a) the students' self-perception and expectations; (b) their interest, engagement and capability in conducting transdisciplinary research, and (c) the students' convictions of scientific knowledge and its development.

2.1 | Real-world problems

Indeed, addressing and defining real-world problems is not easy. "Globalisation, in other words, presents us not only with economic, political and social challenges, but with a huge hermeneutical challenge: a challenge, that is, to our understanding. How, in a world of seemingly incommensurable difference, are we to engage in conversations that are both constitutive of, and conditional upon, shared understanding?" (Nixon, 2017) According to Häberli et al., (2001) transdisciplinary research is useful in topic fields having high anthropogenic interaction, linkages with natural systems as well as tech fields or in development processes. The authors state evidence of transdisciplinarity success in social contexts, for example, education, migration, health, as well as areas of sustainable development, for

TABLE 1 Criteria for transdisciplinary design (own compilation)

Pivotal characteristics of transdisciplinary research[a]	Transdisciplinarity design principles[b]	Things to do[c]
(i) Real-world problems	0. Perception and description of real-world problems	• Recognising and formulating a real-world problem. • Identifying a disorienting dilemma.
(ii) Integration of various disciplines and actors	I. Building a collaborative research team	• Combining scientists of diverse disciplines and non-academic stakeholders in the team. • Initial team-building process.
	II. Joint problem framing	• The entire team frames the real-world problem including the specification of particular interests. • Reflecting on a disorienting dilemma. • Defining key concepts and termini.
	III. Concerted describing the research outline (boundaries, objectives, questions, roles, success criteria, etc.)	• Defining general and specific objectives and questions, and so forth. • Critical reflection.
	IV. Coordinated methodological framework for collaborative knowledge production	• Agreeing on a balanced organisational structure. • Establishing co-leadership and clear responsibilities and tasks. • Selecting tools, methods and criteria for knowledge production. • Defining success criteria for evaluation.
(iii) Cooperation and mutual learning of all actors involved	V. Expedient roles and responsibilities	• Roles and responsibilities are negotiated in the team, defined and reflected in a transparent and valuable manner. • Project leadership facilitates a transdisciplinary approach during the research process.
	VI. Apply and adjust integrative research methods and transdisciplinary settings	• Develop or employ goal-oriented integrative settings and methods.
	VII. Foster capabilities for cooperation and participation	• Feedback loops and ongoing re−/framing of settings and understandings. • Ongoing evaluation of reached goals and process success. • Ongoing reflective discourse. • Ongoing risk mitigation and mediation.
(iv) Production of scientific and other societal knowledge relevant for sustainable development	VIII. Realize two-dimensional integration	• Producing results for both, science and stakeholders taking cultural and further conditions into account.
	IX. Generating targeted products or services	• Providing research outcome in appropriate form and language, for example, round tables, discussions, handouts, publications, services, and so forth.
	X. Scientific and societal impact	• Evaluating direct and indirect impacts. • Evaluating the increase of competences. • Reflective discourse on impact, goals and process.

[a]Based on Tejada et al., 2019.
[b]Amended and adopted from Tejada et al., 2019; Lang et al., 2012; and Luthe, 2017; and Pennington et al., 2013.
[c]Amended and adopted from Tejada et al., 2019.

example, urban and landscape development or waste management. Sustainability issues need to be addressed and discussed from the early beginning (Arnold, 2017), otherwise they lack in potential.

2.2 | Integration of various disciplines and actors

Vermeulen and Witjes (2020) stress the challenges of pluralistic scientific knowledge creation by emphasising the fields of tension in theory approach, like determinism versus integrative perspective and system theory, or research in isolation versus contextualised research and the complexity and uncertainty per se. Disciplines vary in theories and concepts organising expert knowledge as well as in applying definite terminologies or expert language and vary in research methods and procedures (Davis, 2017). The complex nature of sustainability challenges and real-world topics often cannot be addressed by single disciplines (Max-Neef, 2005). Transdisciplinarity is complementary to disciplinarity, interdisciplinarity or multidisciplinarity concepts (also see Mauger et al., 2021). Transdisciplinary scientists combine both, disciplinary excellence and inclusive thinking (Mitrany & Stokols, 2005). So, transdisciplinarity is predestined, but not the sole solution for achieving research and societal goals (Balsiger, 2004). Rottach et al., (2019)

emphasise possible links between science and practice and interdisciplinarity. Transdisciplinarity requires the equal cooperation of all actors. The respective knowledge and experience can complement each other in order to reflect better interdisciplinary learning contexts (Little & Hoel, 2011). Contrasting viewpoints of the cooperation partners can stimulate essential competencies and critical thinking (Buckley, 2000). This is particularly effective when students, scientists and practitioners and external university staff work together in learning contexts. Recognising and acknowledging plural perspectives and using them as arguments and content, these are central skills acquired in practice-oriented transdisciplinary teaching. In cooperative learning context, the results and acquisition of competence often go beyond the mere realisation of a course (Rottach et al., 2019). The acquisition of sustainability-oriented competencies can be strengthened insofar as learning and knowledge acquisition are subject to a process-oriented understanding - and are thus open-ended and dynamic.

For transdisciplinary teaching-learning contexts, various organisational aspects and issues of cooperation are relevant, such as content-related, organisational, material, pedagogical, and so forth, as well as different levels of cooperation (Gräsel et al., 2006). The characteristics of successful concepts include both components of the teaching staff and practice partners, such as personality, the shaping of relationship and organisational-structural factors as well as the student groups, such as their composition in terms of educational background, heterogeneity and consistency as well as group structure (Kummer Wyss, 2017). In the context of organisational-structural factors, the type of university, different resource endowments, teaching obligations, and curricular and examination requirements can affect the success. Rigid exam or module requirements, or a lack of curricular links to trans- and interdisciplinary modules can present obstacles. Therefore, transdisciplinary contexts often require a certain amount of creativity and the use of scope within valid legislation. In addition, in transdisciplinary settings teachers quite often also operate as researchers and exercise different roles.

2.3 | Cooperation and mutual learning of all actors involved

ESD, the Agenda 2030 and sustainability science require transdisciplinary research, modern teaching methods and transdisciplinary methodological settings, such as learning through discovery, experience, research, by solving problems through play, learning by doing and other forms of experiential learning (Matijević, 2012; Riley & Moltzen, 2011; Tennyson & Sisk, 2011). Collaborative learning theories promote social interaction as activities to learn (Cheong et al., 2012; Dale, 1946; Gokhale, 1995). According to Gardner's (2006) theory of multiple intelligence learning, settings should establish several different types of learning and information processing theory. Accordingly, the high autonomy of the learners implies a constant support with the help of the teachers. In transdisciplinary settings teachers need to have good methodological and content-based knowledge and should be able to support the cognitive processes of the co-researchers in an appropriate way. So, there is a continuous need for flexibility of the teaching staff from being an expert to a learning guide and a motivator for the students' learning program. Competence-based learning processes need a specific learning design. According to Matijević (2012) learning objectives, contents, conditions, students' experiences, lecture capacities, economic conditions, legal fundaments and positions of academia determine instructional strategies, media and the learning environment, and thus, impact competencies.

The overall design of the learning process also influences the success in transdisciplinary settings. In transformative science, evidence-based arguments, creative laboratories and scope for experiments play a crucial role. In this sense, transformative science fosters active dialogues "with societal stakeholders and accepts the challenge that comes with this by explicitly questioning and reflecting its own implicit assumptions" (Schneidewind et al., 2016). Therefore, the authors provide a comprehensive overview on different transdisciplinary approaches, transdisciplinary research methods, action research, intervention research or transition research. All conceptualizations have the following issues in common: "they recognize and integrate various types of knowledge, they take a critical stance towards conventional research paradigms and they strive for a new contract between science and society" (Schneidewind et al., 2016). According to Schneidewind et al., (2018) real-world labs are appropriate tools to meet current real-world challenges in complex environments. "In short, they can be described as places of learning, which can have various types of impact: they create socially robust and socially acceptable solutions for actual problems, they serve as testing ground for new knowledge and solutions, and they can facilitate transferability of solutions to other contexts. The basic assumption is that experimenting and learning-by-doing is important not only to initiate change, but also to arrive at a better understanding of transformation processes per se" (Schneidewind et al., 2016). So, a main goal in teaching contexts is that students "reflect on their actions as consumers, citizens and learning human beings" (Schneidewind et al., 2016). And this has to be supported and moderated by the teachers and researchers.

Even cooperation and mutual learning is accompanied by diverse challenges. According to Wallace (2011), the knowledge transfer is the missing link between design practice knowledge of industrial or practical partners and design research knowledge of academic institutions. Fernandez-Orviz, 2021 addresses three main barriers in transdisciplinary contexts: communication (rooted on "language differences" and "intrinsic assumptions" p. 37), uncertain roles and contributions, and discrepancy between self- perception and external perception (see also Fam et al., 2020). Thus, the author recommends the ongoing integration of external mediation in transdisciplinary processes as well as feedback loops and a dynamic understanding of interaction. Yet, she also states "dealing with "professional arrogance" might require a deeper change to our educational systems" (Fernandez-Orviz (2021). Pennington et al., (2013) stress some "transdisciplinary research teams exhibit parasitic characteristics, creating opportunities for innovative outcomes for those from one discipline but not for another. Although they are potentially capable of producing innovative results, parasitic configurations are not desirable, because they generate those results at

the cost of another team member's potential intellectual contribution in other efforts and are not stable, because scientists have the ability to choose whether they participate". Further, the authors emphasise the need of learning how to generate collaborative research providing mutualistic outcomes based on successfully combined and created knowledge across disciplines.

2.4 | Production of scientific and other societal knowledge relevant for sustainable development

Knowledge, relevant for a sustainable development, can be produced in sustainability science and transdisciplinary settings addressing ESD competencies. In sustainability science, fundamental characteristics and interactions between human, society and nature are investigated (Vermeulen & Witjes, 2020)—always progressing social and environmental values and realities. As ESD competencies are extensive and have an enormous breadth and depth, they cannot be fully acquired in transdisciplinary learning or research contexts. The ESD competencies aim at both, a transformation towards sustainability including a high practical orientation in teaching and a research-orientation. Often, transdisciplinary research approaches follow a clear normative description of steps to go and phases to pass. Interaction and cooperation are described to be collaborative, joint or coordinated—presuming equality of values, interests, behaviour and power. However, scarcity, uncertainty, urgency, rule, power or dominance, and change or transition influence cooperation, mutual interaction and knowledge outcome.

Witjes and Vermeulen (2020) also stress three different challenges: inherent, institutional, and teamwork ones. Inherent transdisciplinary challenges include abductive reasoning, dual focus, and iterativeness. Kates et al., (2001) stress "combining different ways of knowing and learning will permit different social actors to work in concert, even with much uncertainty and limited information". The authors further stress particular topics that need to be faced, but at the same time are inherently linked to trade-offs and paradoxes: "(a) span the range of spatial scales between [...], (b) account for both the temporal inertia and urgency of processes [...], (c) deal with functional complexity [...]; and (d) recognize the wide range of outlooks regarding what makes knowledge usable within both science and society". The sectoral separation, for example, water management and farming, and its related responsibilities, adaptabilities and lobbyism also need to be considered. So, facing real sustainability problems, there are different sciences, time- and content-based, structural, legal and governance-related issues and facts causing tensions and conflicts. Among others, these are reasons to foster appropriate principles, criteria and indicators for defining and assessing research quality in transdisciplinary research (Belcher et al., 2016). The authors state relevance, credibility, legitimacy, and effectiveness as main quality drivers for good knowledge production and transfer in transdisciplinary settings. Klein (2008) suggests seven generic principles for evaluating transdisciplinary research:

1. "Variability of goals;
2. Variability of criteria and indicators;
3. Leveraging of integration;
4. Interaction of social and cognitive factors in collaboration;
5. Management, leadership, and coaching;
6. Iteration in a comprehensive and transparent system; and
7. Effectiveness and impact".

Yet, how is the impact of tensions, dilemmas and paradoxes transdisciplinary research?

3 | TENSIONS, DILEMMAS AND PARADOXES IN TRANSDISCIPLINARY RESEARCH

In transdisciplinary research approaches for sustainable development scientific as well as practice-relevant knowledge will be gained and related to each other. The goal is a transdisciplinary co-production of knowledge across the boundaries of different academic disciplines generating knowledge in terms of system knowledge, orientation knowledge, target and design knowledge (Max-Neef, 2005). This is in line with the ESD or UNSECO sustainability competencies. The two-sided knowledge and different forms of knowledge will increase the better understanding of local and global challenges as well as provide and support the implementation of solutions and new approaches to meeting current and future challenges. Expert knowledge, empirical knowledge and scientific knowledge need to be integrated and linked up to a comprehensive level, which requires mutual recognition in the forms of knowledge as well as the willingness to overcome one's own understanding of roles and the willing to walk in another's shoes (Umemoto, 2001). An emergent issue of transdisciplinary designs is: there are differences in knowledge and values causing tensions, unintended consequences or dilemmas.

Tensions occur in situations, in which different needs or interests cause difficulties. Especially in social contexts and circular or interdependent settings unintended consequences can occur, for example, windmills are causing local climate change and infrasound, or efficient lightning causes an overconsumption of energy, or efficient cars create more kilometres to be driven. Addressing real-world problems and solving real-world challenges must take tensions and unintended consequences into account, in fact, the whole transdisciplinary process with it. Tensions and unintended effects are not only an issue of content, they are an issue of cooperation, communication and action or realisation as well. Bulten et al., (2021) highlight the tensions self-perception and expectations of different stakeholders as well as societal beliefs on what constitutes (scientific) knowledge including how it should be established.

Other challenges that need to be faced in transdisciplinary settings are dilemmas. Dilemmas are "wicked problems" or settings, in which a person has the impression or is forced to choose either difficult or unpleasant things in the same manner. Rittel and Webber (1973) state: "Whenever actions are effectively irreversible and whenever the half-lives of the consequences are long, every trial count. And every attempt

to reverse a decision or to correct the undesired consequences, poses another set of wicked problems, which are in turn subject to the same dilemmas." In corporate sustainability studies, Van der Byl & Slawinski (2015) studied, how conflicts are investigated. They revealed the four distinct win-win, integrative, trade-off, and paradox lenses that are used for conflict analysis. In win-win strategies, tensions are avoided through alignment/optimization of sustainability elements (Van der Byl & Slawinski, 2015). The integrative perspective manages tensions by shifting focus from economic to social and/or environmental ones. Trade-off contexts often have a dilemma structure. But, in trade-off contexts tension is avoided by choosing a sustainability dimension before another one. Augenstein et al., (2020) identified three main dilemma "connected to core aspects of transdisciplinary research on sustainability transitions: (a) inter- and transdisciplinary knowledge integration (Babylon dilemma), (b) foundational theories of change impacting science-policy collaboration (simplification dilemma), and (c) political or strategic concerns in science-practice collaborations with grassroots initiatives (scaling-aversion dilemma)." Ad 1., the authors stress diverse underlying (conflicting) conceptualizations, ontologies, epistemologies and expertise leading to constant dilemmas. Ad 2. (Augenstein et al., 2020): "The Simplification dilemma addresses the conflict between "getting a grip" on desired processes of change by condensing them into simple terms and replicable practices versus the need to understand and embrace the complexity of social change and to accept that innovation and transformation is neither predictable nor controllable." Ad 3. The dilemma addresses the potential loss of the original core identity of emerging sustainability solutions or innovations when growing in scale whereas remaining in a unique niche.

The paradox approach accepts and explores tensions rather than resolution. Paradoxes are "contradictory yet interrelated elements that exist simultaneously and persist over time" (Smith & Lewis, 2011). So, there are different possibilities to address tensions, dilemmas and paradoxes in transdisciplinary settings. In the context of innovation – and this is strongly linked to transdisciplinary research and framed goals, either in overcoming the joint problem or alternatively in generating targeted products or services (see Table 1)—paradoxes play a pivotal role. First of all, Sauer (1999) stated "the paradox is; innovations depend on conditions that cannot be fulfilled precisely at the time, because they involve the creation of something new—conditions that must first be discovered, produced and tested in the course of the innovation itself". There are several paradoxes linked (Sauer, 1999):

1. The paradox of time and sustainability: The social, ecological and economic impact of new technologies cannot be fully assessed in advance as not all interdependencies can be estimated or simulated. Within their use and dynamics of development real and potential uses and damage emerge. Intended and unintended effects can occur, new lock-ins (Svingstedt, 2018) and path dependencies (David, 1994) singularize. Thus, in transdisciplinary research, participants must have this issue in mind and all contributors need to reflect on it during the whole process. It is not only an issue of content; it is also an issue of communication and reflexivity as well as moderating the transdisciplinary process.
2. The paradox of contextualization: The present contexts of use strongly influence the development of technologies. Thus, the active construction of fields of application and markets is an essential factor for the success of innovation itself. However, knowledge-based innovations require a re-contextualised R&D - beyond contexts of application. Yet, the success of re-contextualization is inherently linked to the embedment in social contexts of use. This implies or results in the invention and institutionalisation of new markets. This paradox is more or less a homage to trans- and interdisciplinarity, as different systems of thinking is needed to be successful in terms of sustainability. Having ongoing awareness of this paradox, transdisciplinary settings can come up with fruitful results as well as a pure risk management for implementation.
3. The paradox of global/regional innovation conditions: On the one hand, innovation networks can only emerge and survive in a socially strong structured environment, and this environment is still characterised by cognitively, socially and spatially defined and restricted references. On the other hand, there is an increasing need to transcend these previous boundaries with the consequence of the aforementioned "dis-embedding" of innovation contexts (Sauer, 1999). Transformation towards sustainability is needed, and transformation is embedded in past and current structures and systems. Path-dependencies (Stack & Gartland, 2003) hinder progress towards sustainability, but ground-breaking progress is necessary for local and global change towards habitat, preserving real-world solutions. The thinking of transdisciplinary developed products or services without a thinking of social, political and legal embedment will fall short. Here, thinking in possibility spaces (Sinner, 2018; Möglichkeitenräume) and transdisciplinary labs (Schäpke et al., 2018) for elaborating real-world conditions, become pivotal.
4. The paradox of legal controllability: Promoting innovation by law, regulation is needed before innovations become reality. Being able to set regulations enabling innovation(s), knowledge about, experience with, as well as evaluation criteria for the innovation(s) and the effects are necessary (Sauer, 1999). However, these can only be reliably obtained in the momentum the innovation has become reality and is part of social interdependences. This fact also affirms transdisciplinarity; however, makes it difficult to evaluate solutions within the conventional time frames of transdisciplinary settings.

Indeed, these diverse tensions, dilemma and paradoxes are inherent in transdisciplinary contexts and are often underexposed.

4 | RESEARCH DESIGN AND METHOD

Giving answers to the research questions, research and teaching settings should be distinguished. As stressed above, in academia, researches have to fulfil different roles in two main settings – research and teaching (see Box 1): transdisciplinary learning-teaching concepts and transdisciplinary research projects, for example, labs or other types of cooperation. There are differences between transdisciplinary

BOX 1 Example of transdisciplinary projects and experiences - case study background (own source)

Research/research projects	Lectures
Transdisciplinary research was conducted in product-related participation processes, for example, in cooperation with a small German bike company, diverse citizens and scientists from business management, industrial engineering, politics, physics and geography. Core goal was the improvement of urban mobility. So, the focus was set on the development and embedment of bicycles and electric bicycles or pedelecs. Pedelecs, as bicycles with electric pedal assistance, allow a higher speed and greater range than conventional bicycles, the required electricity can be got by means of regenerative energies, and therefore pedelecs can be seen as attractive. At the same time, they are seen as a more environmental and climate-friendly alternative to cars, motorcycles or scooters. This was also seen by a developed life cycle assessment simulating the environmental impact of different modes of transport. The developed tool was integrated into the transdisciplinary research process and applied by various stakeholders. Another research project was the joint development of future integrated housing and mobility innovations by focus groups containing practitioners and company representatives, citizens, representatives of the municipality, and researchers. The joint development of ideas and solutions was supported by the use of LEGO® and mind mapping visualisation. Additional transdisciplinary research was conducted in the forest area, elaborating requirements and innovations of the forest value chain. Participants were researchers, architects, craftsmen, representative of home improvement stores, local politicians, farmers, customers, and so forth.	In lecture contexts conducting transdisciplinary research takes place in seminars applying specific learning concepts as well as cooperation with company representatives, urban planner, local politicians and NGOs. In either cross- or inner-university settings bachelor and master students from different topics, for example, industrial engineering and economics, work together with academia external stakeholders to investigate a real-world sustainability problem. Applying topics in the context of sustainability, for example, biodiversity, bioeconomy, circular economy, rebound effects, and so forth, joint problem framing and research are addressed. Facing the research topics appropriate tools are introduced and applied, like methods of sustainability assessment, SCRUM, design thinking or LEGO®. SCRUM - as an agile alternative to classical project management, based on the insight that a quick reaction to changes is more successful – enables the increase of agile and practical skills as well. LEGO® can also support the knowledge production process by simulating the ideas in 3D and collectively explaining and showing own frames. The students develop(ed) concrete sustainable ideas and test(ed) them for their sustainability impact and applicability cooperatively.

research projects and transdisciplinary interaction and cooperation within teaching contexts as in teaching researchers also have to cope with the role of learning facilitator, mentor, tutor and knowledge gatekeeper. Transdisciplinary research projects include joint projects to address or solve real-world sustainability problems integrating scientists and non-academic stakeholders, such as company representatives, NGO representatives and citizens. Transdisciplinary teaching concepts comprise learning settings in which students interact with non-academics to develop real-world sustainability solutions. These learning concepts are often integrated in curricula, and thus, passed with any kind of exam (credit points) and accompanied by clear competencies and learning goals. Thereby, different scholars can be followed. Analysing transdisciplinary scholars Vermeulen and Witjes (2020) identified three main pivotal groups: intra-academic transdisciplinarity, (characterised by theory development and instrumental stakeholder integration), solution-driven transdisciplinarity, (characterised by more extended stakeholder integration for solving problems and developing concrete concepts), and fairness-driven transdisciplinarity, (characterised by clear empowerment and stakeholder inclusion – often vulnerable stakeholder groups). The described examples in Box 1 follow the scholar of solution-driven transdisciplinarity (see Vermeulen & Witjes, 2020).

Therefore, higher order reflections on the research questions are based on both, analysing tensions, dilemmas and paradoxes along the typical transdisciplinary design phases (see Table 1) and on the experiences made conducting transdisciplinary cases in research and teaching contexts, in economics and business management at different German universities from 2005 until now. Obvious and hidden tensions, dilemma and paradoxes shall be discussed in line with the given transdisciplinary design criteria, so own experiences will be embedded in this reflection and shall enrich the higher order reflection exemplary. In order to analyse tensions, dilemma and paradoxes, the single aspects of transdisciplinary research design are investigated criteria-based. Therefore, the transdisciplinary design criteria—as provided in Table 1—were used as qualitative analysis codes for compiling methodological as well as empirical learnings and reflections. The main goal of this work is amending and revising the current understanding (see Jaakkola, 2020) of the grounded framework of transdisciplinary research provided in Table 1, and thus, provided revised in Figure 1. Consequently, the underexposed perspective of teaching concepts and lecture roles shall be highlighted. Pivotal tensions, dilemmas and paradoxes should be identified and discussed for typical research as well as teaching settings in academia for widening the current framework.

5 | RESULTS

Table 2 clusters pivotal tensions, dilemmas, and paradoxes in transdisciplinary settings as well as roles and challenges of transdisciplinary

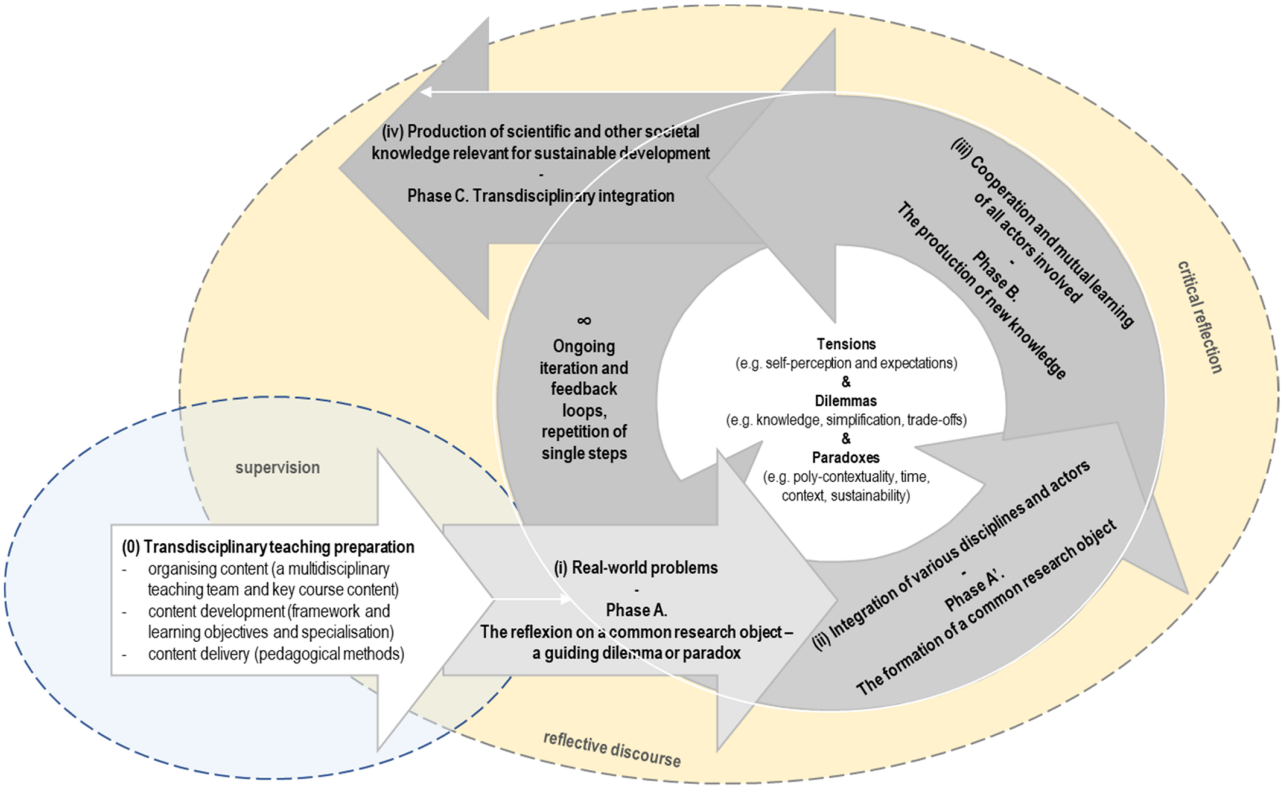

FIGURE 1 Transdisciplinary phases seen in a more circular perspective and amended by teaching [Colour figure can be viewed at wileyonlinelibrary.com]

researchers that go beyond classical research settings. Only some aspects should be highlighted in the following.

5.1 | Real-world problems

Typical tensions are the dominance of one stakeholder group or the missing of actual interest from a joint partnership for solving real-world problems. (Teaching) Researchers must continuously reflect their own stakes in the interaction and are forced to balance interests. The main challenge is to identify hidden interests and perceptions or hidden agendas when defining real-world problems (see Bulten et al., 2021). Trust and sincerity can be simulated—from all stakeholder groups, including the teaching or academic side. Especially if there is funding pressure in academia (Witjes & Vermeulen, 2020) or a good opportunity to gain knowledge in practice, transdisciplinary settings can be negotiated, but not intentionally to solve real-world problems, but only to analyse and reflect on it. Extremely risky or highly secured topics will not be part of transdisciplinary settings. The dilemma to solve is either to conduct diluted transdisciplinary research or skip. From the paradox side it is difficult to describe the problem without framing the context in past and path-dependencies. The level on which the problem is perceived and described, already determines the solutions. The (teaching) researcher's role is to reflect on and initiate consciousness on it constantly; however, even academics are bound to their own frames and white spots. So, in terms of sustainability the definition of real-world problems can result in an under-complex and strongly limited and locally grounded task. The main difference of transdisciplinary researchers or lecturers to other research context, is here to keep the transformational and practical perspective in mind and moderate the self-determination of perceptions and knowledge of the different stakeholders. In addition, defining real-world problems, there is a vivid difference between transdisciplinary research projects and lecture modules. For instance, in Germany in academia in business management, transdisciplinary research projects often start in more or less given settings, that means, the overall topic, for example, mobility, housing, textiles, and so forth, is already determined due to funding reasons aiming at a clear output and outcome. Whereas, in lecture settings there are more degrees of freedom concerning topic and conditions.

5.2 | Integration of various disciplines and actors

The lack of complementary knowledge may cause unintended effects like time delays in forming a common language or choosing "lemons" in adverse selection processes due to information asymmetry (Akerlof, 1970). Loosing time and negotiating the lowest level or lowest common denominator are comprehensible in multi- and transdisciplinary settings, but not functional for best case and good practice solutions. The choice of the appropriate outline and methods has

TABLE 2 Tensions, dilemmas, paradoxes in transdisciplinary settings including changed roles of researchers (own compilation)

Pivotal characteristics of transdisciplinary research (TR)[a]	Transdisciplinarity design principles[b] and Things to do[c]	Challenges, tensions and unintended consequences	Dilemmas	Paradoxes	Changed or additional roles of researchers in transdisciplinary research/projects	Changed or additional roles of researchers in transdisciplinary teaching/modules
(i) Real-world problems	0. Perception and description of real-world problems Recognising and formulating a real-world problem.	• Overall topic often pre-determined in lecture contexts more openness, but dependent on lecture topics, faculty contents and students' interests • Domination of a stakeholder group – either researchers or practitioners • Different perceptions of sustainability – balancing and integrating diverse sustainability dimensions • Is there need for action? • Who has a clear interest of solutions? • Is TR honoured or at least not hindered by the (academic/company) performance indicators?	• Transactional costs of cooperation • Information bias and security issues • Normative, positive or descriptive theorising • Dominance of scientific-theoretical or practical perspective or investigation	• "Either you already know what you want to know, or you don't know. If you already know it, then it will be unnecessary to search for it. But if one does not know it, the search will be impossible; for one cannot find anything that one does not know." (Platon: Menon 2019) → What is the hidden reason for transdisciplinary cooperation? What is the core topic of joint research and cooperation? • Self-determination of perceptions and knowledge • Path-dependencies of self-determination in problem definition • Innovation paradoxes can only be addressed and reflected, but not solved	• Researchers as experts and moderators • Much more preparation of contents and knowledge acquisition in order to understand different perspectives better and adequately moderate perceptions and descriptions of real-world problems → need to understand whether the described problem is a factual sustainability one	• Dual roles as coaches and expert • Triple role as instructor and tutor as well as motivator for collegiate learning processes • Need to triangulate and "translate" knowledge gaps and wording to students • Need to make sure students understand the real-world problem and the given challenges • Need to organise a sequential learning and reflexion process for students – leads to more work load
(ii) Integration of various disciplines and actors - Phase A. The formation of a common research object	I. Building a collaborative research team - Combining scientists of diverse disciplines and non-academic stakeholders in the team. - Initial team-building process.	• Lack of appropriate and necessary professions or practitioners • Students interested both in the examination of theories and in practical project work • Lack of diversity • Obligation to cooperate (due to funding) versus lack of funding • Inclusive versus exclusionary thinking	• Disciplinary excellence versus cross-disciplinary tolerance • Are qualifications (skills and competencies) a prerequisite for admission (based on which criteria) or taught in the process? • Free participation versus elite selection • Suitable periods and rooms versus semester planning	• Transdisciplinary research implies a higher significance of key qualifications such as coordinative skills, project management, media competence and communication skills as well as a high level of social competence – people primarily learn by doing. → at the same time learning contexts shall enhance such skills and competencies. Either exclusionary settings or second-best scenarios in teaching.	• Researchers as process stabilisers for trust building in big and diverse groups • Researchers as experts and moderators – often co-moderation necessary to widen perspectives and acceptance • Need for supervision avoiding blind spots in the selecting process • Building bridges between research paradigms and termini • Unfold reciprocal attributions for a more open-minded discussion • The more participants, the greater the organisational effort • Mediating the poles of clarity (controllability) and diffusivity (openness to surprises).	• Triple roles • Often co-moderation not possible as cooperative lectures are rather unusual → need for supervision (but often limited by resources) • Building bridges between research paradigm and termini and knowledge or competence gaps • Unfold reciprocal attributions for a more open-minded discussion • The more participants, the greater the organisational effort • Reserving lecture time for reflecting the different interests of stakeholders with students to better understand the process • Mediating the poles of clarity (controllability) and
	II. Joint problem framing - The entire team frames the real-world problem including the specification of particular interests. - Defining key concepts and termini.	• Development of a "common language" (Tejada et al., 2019) is an ongoing and non-determined process and characterised by interaction processes • Dominated sustainability dimension based on selective interests	• Persisting in causality thinking instead of scenario thinking • Persisting in contextuality instead of mind shifting • Time restrictions versus sufficient problem framing	• Poly-contextuality – different perceptions, experiences and consciousness are not able to synchronise → different perspectives are inherent → need for ongoing connectivity		

TABLE 2 (Continued)

Pivotal characteristics of transdisciplinary research (TR)[a]	Transdisciplinarity design principles[b] and Things to do[c]	Challenges, tensions and unintended consequences	Dilemmas	Paradoxes	Changed or additional roles of researchers in transdisciplinary research/projects	Changed or additional roles of researchers in transdisciplinary teaching/modules
	III. Concerted describing the research outline (boundaries, objectives, questions, roles, success criteria, etc.) - Defining general and specific objectives and questions, and so forth.	• System, target and transformation knowledge are unequally balanced within the team and can cause tensions • Design of competence-based learning process (Matijević, 2012) insufficient or based on false conditions → tensions of learning settings and TR needs	• Design of competence-based learning process versus given transdisciplinary realities and necessities • Limitation of time versus appropriate choice of tools • Chicken-and-egg problem of degree of freedom in commitment on learning design	• Ongoing re-contextualisation • Circularity and iteration of boundaries, objectives and questions • Paradoxes of innovation or problems solutions	• Balancing (intra-) scientific disputes and clarification processes for transdisciplinary cooperation and integrative perspectives • Identifying secondary or hidden interests of stakeholders – maybe manipulating the openness	diffusivity (openness to surprises). • Balancing (intra-) scientific disputes and clarification processes for transdisciplinary cooperation and integrative perspectives • Tolerating the tension: Guiding the learning process versus openness of the transdisciplinary process • Identifying secondary or hidden interests of stakeholders – maybe manipulating the openness
	IV. Coordinated methodological framework for collaborative knowledge production - Agreeing on a balanced organizational structure. - Establishing co-leadership and clear responsibilities and tasks. - Selecting tools, methods and criteria for knowledge production. - Defining success criteria for evaluation.	• Often rather normative description and requirements • Officially all views are considered, but practically, either scientific or stakeholder views dominate • Conflicting methodological standards (Lang et al., 2012)	• Coordination by control or agility • Lack of integration due to path-dependencies or high costs	• "Either you already know what you want to know, or you don't know. If you already know it, then it will be unnecessary to search for it. But if one does not know it, the search will be impossible; for one cannot find anything that one does not know." (Platon: Menon) → Tool, methods and criteria for knowledge production need an ongoing reflection and case-wise alignment.		
(iii) Cooperation and mutual learning of all actors involved - Phase B. The production of new knowledge	V. Expedient roles and responsibilities - Roles and responsibilities in the team are negotiated, defined and reflected in a transparent and valuable manner. - Project leadership facilitates a transdisciplinary approach during the research process.	• Insufficient participation • Unbalanced problem ownership (Polk, 2014) • Willingness to overcome one's own understanding of roles (to walk in another's shoes) • Lack of mediation • Change or stop of cooperation	• Conflict resolutions/ mediation versus content-based work	• Poly-contextuality – different perceptions, experiences and value concepts are not able to synchronise → ongoing negotiation	• Open attitude and social competence of the researchers involved: Bring openness to others, enjoy contact with people and a certain robustness and frustration tolerance • Managing two ongoing levels of activity: content and social-communication • Defining result spaces	• Open attitude and social competence of the researchers involved: Bring openness to others, enjoy contact with people and a certain robustness and frustration tolerance as well as enduring role ambiguities • Managing three ongoing levels of activity: content, social-communication and learning/competence enhancement • Defining result spaces in two ways: transdisciplinarity and learning outcome
	VI. Apply and adjust integrative research methods and transdisciplinary settings - Develop or employ goal-oriented integrative settings and methods.	• Not all methods are equally appropriate for all sustainability dimensions • Knowledge transfer of tools time-consuming or second-best solutions	• Knowledge of appropriate methods versus application and joint use • Ambiguity of results • Value or scale-based approach	• Poly-contextuality → ambiguity of results		

(Continues)

TABLE 2 (Continued)

Pivotal characteristics of transdisciplinary research (TR)[a]	Transdisciplinarity design principles[b] and Things to do[c]	Challenges, tensions and unintended consequences	Dilemmas	Paradoxes	Changed or additional roles of researchers in transdisciplinary research/projects	Changed or additional roles of researchers in transdisciplinary teaching/modules
	VII. Foster capabilities for cooperation and participation - Feedback loops and ongoing re-/framing of settings and understandings. - Ongoing evaluation of reached goals and process success. - Ongoing risk mitigation and mediation.	• Unbalanced empowerment in skills and competencies	• Transactional costs: time for coordination, communication and teaching of methods versus time for the development of solutions (scientific excellence or practical progress)			
(iv) Production of scientific and other societal knowledge relevant for sustainable development - Phase C. Transdisciplinary integration	VIII. Realize two-dimensional integration - Producing results for both, science and stakeholders taking cultural and further conditions into account.	• Specialist, empirical and scientific knowledge must interact and be linked at the same level, which presupposes mutual recognition of the forms of knowledge • Limited options for either one side	• Conflicting effects concerning spatial, temporal, regulation levels	• Task of knowledge production, processes, evaluation bases and design options examined from a scientific perspective AND considering the culture, interests and needs of local actors • Local contexts versus global conditions and interdependences	• Creating conditions for the possibility of transdisciplinary knowledge production and integration going beyond project management • Providing information in disciplinary, transdisciplinary, practical and other journals, including science communication • Establishing long-term observation (often against given structures and funding)	• Creating conditions for the possibility of transdisciplinary knowledge production and integration going beyond project management • Providing information in disciplinary, transdisciplinary, practical and other journals, including science communication → learning settings also address pedagogical journals and students involved communication
	IX. Generating targeted products or services - Providing research outcome in appropriate form and language, for example, round tables, discussions, handouts, publications, services, and so forth.	• Reduction of complexity of scales can lead to misuse or results • One-sides solutions	• Coercion of final products versus processual insights or step-wise solutions	• Contexts limit to incremental solutions • Chance is not included in TR settings		
	X. Scientific and societal impact - Evaluating direct and indirect impacts. - Evaluating the increase of competences.	• Self-fulfilling prophecy based on problem framing (project success instead of failure)	• Short-term versus long-term impact • Friction of diverse sectoral levels	• Innovation paradoxes • Poly-contextuality → who and on what scale or level is assessed?		

[a]Based on Tejada et al., 2019.
[b]Amended and adopted from Tejada et al., 2019; Lang et al., 2012; and Luthe, 2017.
[c]Amended and adopted from Tejada et al., 2019.

almost always dilemma structure, as different disciplines need specific methods reaching excellent solutions. Recognising the need for diversity and variety and either moderating the mitigation of these tensions or making sure that the tensions will be mitigated and moderated by external process facilitator is the main job of the teacher or researcher in this phase. The paradox of poly-contextuality needs a constant reflection. The joint problem framing is often normatively empowered, however, in systemic sociology approaches, poly-contextuality (Saake & Nassehi, 2007) leads to ongoing communication that is not able to synchronise different perceptions, experiences and values. So, although all team partners agree on a joint understanding or definition of real-world problem, 1 s later, this agreement is forgotten and leads to ongoing communication about what the real real-world problem is.

Transdisciplinary researchers must address the Babylon dilemma explicitly and poly-contextuality continuously. The visualisation of jointly framed problems and variety and circles of methodological tools, are more necessary compared to other research work. The researchers should also establish frequent reflexion rounds for ongoing re-contextualisation and white knowledge spots. There needs to be repetitive knowledge inputs and a return to standard definitions (topics, concepts, joint problem framing, etc.).

5.3 | Cooperation and mutual learning of all actors involved

The researchers have to balance the communication, clear and appreciative understanding and the content or knowledge outcome continuously. Poly-contextuality is a main challenge as more persons from different contexts and backgrounds have more and differentiated perceptions, experiences and values. Here, the researchers have ongoing negotiations and communications. Graf and Ukowitz (2020) stress that transdisciplinary researchers operate on two ongoing levels of activity: "a content level, where the focus is on generating knowledge, and a social-communicative level, where the focus is on the processes of knowledge generation, but also on the dimension of practice transfer". In lecture contexts, there is a third level, too: the researchers must manage the collegiate learning as well as competence process.

5.4 | Production of scientific and other societal knowledge relevant for sustainable development

The cycle of the production of knowledge (Witjes & Vermeulen, 2020) is not always based on curiosity. Sometimes there are hard corsets due to learning settings and project funding. In this case, an unintended side-effect is the self-fulfilling prophecy of transdisciplinary results due to the problem framing at the beginning of the process. Clear dilemmas occur when conflicting effects exist, concerning spatial, temporal and regulation levels or diverse sectoral levels, have different benefits integrating the solutions. Here, the paradoxes also reveal poly-contextuality and different conditions for local and global success.

In transdisciplinary settings the researchers need to define result spaces, as participatory does not work and automatically leads to outcome. The teachers and researchers can only motivate and reflect for good implementation conditions in practice and make sure that the knowledge production is given in terms of the intra-academic transdisciplinarity concept. Researchers must create conditions for productive knowledge production and long-term observation. In teaching settings, the researchers also need to integrate the students for active scientific communication.

6 | DISCUSSION

There are various issues changing the role of the researchers in transdisciplinary settings managing unintended effects, tensions, dilemma and paradoxes aiming at successfully organised transdisciplinary processes.

6.1 | Real-world problems

As the concept of sustainability is often accompanied by diverse understandings of sustainability, and own interests, there might be an inherent misbalance of the sustainability dimensions (see Van der Byl & Slawinski, 2015). The researchers need to address and reflect on it and initiate ongoing communication about it (Bulten et al., 2021). This is important and different from classical research settings as transdisciplinary settings aim at knowledge integration. Innovation paradoxes and path dependencies determine the scope of real-world challenges. In transdisciplinary settings, they often result in incremental solutions as the integration of many disciplines and stakeholders leads to the lowest common denominator. As good as multi- and transdisciplinary perspectives are, as incremental or viable solutions can be. Depending on the underlying challenges—scarcity, uncertainty, rule, power or dominance and change or transition—multidisciplinary settings are better or worse suitable to come up with appropriate solutions. Like in team work or innovation processes, clear effort and a positive contribution of ongoing cooperation and transdisciplinary work still need to be assessed and clearly progressed by the researchers.

The innovation paradoxes have to be reflected from the early beginning in order to be able to establish a new innovation paradigm and a ground-breaking shift towards sustainability. So, researchers have to balance an open formulation of a real-world problem and their own intervention when giving input on sustainability paradoxes, reflexions and widening perspectives. This is different as they normally can focus on their own research interests and outcome. Moreover, transactional costs can prevent transdisciplinary research as daily tasks do not allow the search of cooperation partners. Thus, researchers have to moderate and engage for vivid engagement and to empower different stakeholders contributing to a joint cooperation without forcing them. In lectures, researchers should motivate the students to engage with concrete real-world problems by reading, making interviews and selecting further data, so, they can really develop own perceptions and

descriptions of real-world problems (see Bulten et al., 2021). Otherwise students become a less engaged stakeholder group in transdisciplinary processes. Indeed, actually, it needs to be defined WHO is recognising and formulating a real-world problem – this should also be a joint process. Referred to Tables 1 and 2 the steps 1–3 [(i) real-world problem: 0. and (ii) integration of various disciplines and actors: I. + II.] are rather iterative and circular than sequential. In fact, I recommend integrating the real-world formulation into phase A (see Figure 1).

6.2 | Integration of various disciplines and actors

The formation of a common research team and research objective is most challenging (Schmidt & Pröpper, 2017). Depending on the initial idea and definition of a real-world problem the formation of a research team and the joint problem in all, are time-consuming and often dominated by being mainly one-sided. Either the obligation to cooperate, for example, by funding, or the lack of funding can strongly influence the degrees of freedom in transdisciplinary research. Although a real-world problem is identified, this does not mean inherently that is it even clear what kind of experts and disciplines will be needed to solve the problem. This can result in a lack of diversity and have impact either on the ongoing group formation and communication processes, or on the quality of results, or both. In this phase, a clear paradox is that transdisciplinary research implies a higher significance of key qualifications such as coordinative skills, project management, media competence and communication skills as well as a high level of social competence, while people primarily acquire competencies by doing. At the same time transdisciplinary learning contexts should enhance such skills and competencies. So, preconditions need to be defined, resulting in exclusionary settings—but the main question is from whom and of what kind. Here, researchers have to deal with all different kind of roles. Moreover, interested or voluntary students and scientists enhance transdisciplinary and other skills—often resulting in second best scenario teaching. That means, inherent dilemmas are faced in this phase. In addition, in lecture settings the time, scope and rooms are restricted by a semester logic—this is often far too short for transdisciplinary settings; so, small scale projects will be offered—limited in all phases of transdisciplinary research.

Graf and Ukowitz (2020) point to the fact that it is crucial which persons from academia and/or practice are involved in project development. They (Graf & Ukowitz, 2020) further state: "The larger and more heterogeneous the project group, the less predictable it is how the participants will settle into a joint project, and trust must first be developed or it must first be proven in the process that the leap of faith, with which the participants enter into a project, is justified". This kind of responsibility of the researchers goes beyond traditional research projects often having clear goals and functional cooperation. Besides, not having a "common language" communication is an ongoing process, indeed, joint problem framing as well. This also includes the determination of research tools and methods. As there are knowledge gaps between the two-sides, content-based input would be needed to come to a minimum of methodological knowledge. This would be time-consuming and cause opportunity costs as well. It would also need the interest of the project partners to learn additional facts and skills. Within time the knowledge bases increase an ongoing re-contextualization, including circularity, and the iteration of boundaries occurs. The chosen methods and tools do not appear to be appropriate and only seem to be second best. Frameworks for knowledge production lack in acceptance or dominate one partner's perspective. Researchers need to be knowledge-brokers, facilitators, mediators and supervisors at the same time.

Defining and describing the research outline is leading to several teaching problems. The design of a competence-based learning process (Matijević, 2012) actually needs to be analysed and configured before starting transdisciplinary research; yet, transdisciplinary research follows own design processes (e.g., Lang et al., 2012; Luthe, 2017) that are not strictly in line with competence-based designs. Learning objectives, contents, conditions, students' experiences cannot fully be influenced and guided in transdisciplinary settings. Lecture capacities, economic conditions, legal fundaments and positions of academia are often fixed and impact on the transdisciplinary design. As the instructional strategies, media and the learning environment are jointly created, in transdisciplinary settings teachers cannot control a clear acquisition of competencies any more. In the Bologna system the different previous knowledge and competences of the students differ due to the type of university and course of studies. The number and the distribution of students are often determined by curricular and examination-related factors and reflect the organisational-structural realities of academia. Even teachers or lecturers have different educational backgrounds and knowledge, training and didactic ideas for conducting transdisciplinary research. The open and dynamic teaching-learning design also requires the ability of teachers and tutors to engage in learning processes spontaneously to build up new understanding of teaching roles and to accompany students with relative knowledge advantages. They must also be able to adapt to new and unforeseen needs and conflict resolutions.

Finally, although Phase A (see Tables 1 and 2) is emphasising frames of common, joint, concerted, collaborative, and so forth, it needs to be kept in mind that it is more or less about physical interaction. Considering poly-contextuality, this phase is characterised by ongoing negotiation and exchange of perceptions and recognitions, values and experiences. In fact, there is no joint, there is a kind of vivid plus, something that is more than its parts. Transdisciplinary design principles and characteristics should also address these issues and maybe reframe cooperation principles, like exchange, interaction, defined or explicit goal, and so forth. A circular representation of transdisciplinary designs could be more helpful (also see Figure 1). One option is the illustrated cycle of transdisciplinary research by Witjes and Vermeulen (2020). This would also give more consideration to the constant iteration of researchers' roles.

6.3 | Cooperation and mutual learning of all actors involved

The production of joint and new knowledge is predominantly influenced by poly-contextuality and the paradoxes of innovation. The ambiguity of results often leads to simplification and dominant

diffusion or one-sided usability. In this phase, the willingness to cooperate and walk in another's shoes are pivotal, otherwise mediation and conflict resolution dominate the pragmatic knowledge production in effective ways (Wamsler, 2017). Greenhalgh-Spencer et al., (2017) stress that "being pulled up short" is a pivotal type of teaching and learning in transdisciplinary contexts, because it "involves exposing a blind spot. It is the moment when your own understanding and expectations fail to encompass the circumstances with which you are faced. It is the moment where you have to rethink. In order to create or facilitate those moments of being pulled up short, teachers aim to create moments of disruption, conversation and openness to make a difference."

The unbalanced empowerment of skills and competencies can cause conflicts between methodological schools and value or scale-based approaches. Some cases offer that "The journey is the reward." and the production of new knowledge. Some transdisciplinary cases show that personal development and individual acquisition of competencies are the hidden goal of transdisciplinary research. The production of transferable new knowledge is not really aimed at. Here, the "Babylon dilemma can be usefully sustained to accommodate conceptual plurality, thereby reserving time and resources in transdisciplinary research processes to establish a reflexive dialogue between researchers and practitioners from different fields" (Augenstein et al., 2020). This is a clear task for moderating researchers or teachers. From a systemic perspective, moderating actors should not be part of the transdisciplinary team itself, otherwise it would hinder or disturb interaction processes (Arnold, 2016).

Although according to Gadamer (1992) a teacher is always a learner, and all learners always have vital stories and thrilling lessons to tell, transdisciplinary researchers need a bit more. Graf and Ukowitz (2020) point to the fact, that the attitude and a certain degree of social competence of the researchers involved are essential for the success of transdisciplinary research. Moreover, they state, researchers have to like the form of research, need to have a "certain openness to others, enjoy contact with people, and have a certain robustness and frustration tolerance" Graf and Ukowitz (2020).

6.4 | Production of scientific and other societal knowledge relevant for sustainable development

The transdisciplinary group needs to define result spaces as the paradoxes of innovation are particularly effective in the phase of knowledge production. This is in line with the recommendation of Graf and Ukowitz (2020): "Participatory research processes do not always lead straight clearly to defined and immediately visible results. Defining result spaces provides orientation and makes it possible to generate and use research results on several levels." Here, researchers have to create conditions making it possible. The task of knowledge production, processes, evaluation bases and design options have to meet both, the scientific requirements (de-contextualization) and the culture, interests and needs of local actors (contextualization). Local contexts versus global conditions and interdependences should be met as well (see Sauer, 1999). Thus, solutions are often limited to incremental, path-dependent solutions or are extremely visionary, so that they cannot be implemented. The force to produce products or services having a scientific and societal impact hinder the development of step-wise or processual insights not being able to fill glossy brochures, handouts, guidelines or supermarkets. Conflicting effects and impacts on spatial, temporal and regulation levels bring different decision dilemmas for different disciplines (Polk, 2014). Transdisciplinary researchers have to make them transparent and mirror them into the group. The simplification of complexity leads to the misunderstanding of insights and results and might end up in a kind of misuse of results. Results in students' settings are often one-sided solutions and show some dis-balance of sustainability dimensions. Fritz and Meinherz (2020) highlight the role of power in transdisciplinary processes. They stress the power of researchers, especially for disseminating results: "the researchers partly responded to the implicit or explicit expectations of funders and practitioners who, to varying degrees, wielded power over dissemination practices or requested that dissemination formats be adapted so as to increase their usability" (Fritz & Meinherz, 2020).

The researchers also have the power to empower. This is in line with the suggestions of Augenstein et al., (2020) handling the simplification dilemma—and even goes beyond: "paying greater attention to the following factors: the promotion of open-ended and reflexive experimentation, an adjustment of measures in view of their impact and a focus on the long-term observation of initiated processes of change". The main question here is, who is observing long-term transformation? Having traditional research projects or transdisciplinary lectures in academia in mind, there are people working in transdisciplinary context only time limited, for example, students, project members, and so forth. There is a definitive lack of opportunity and responsibility in such academic transdisciplinary settings for ensuring long-term observation. Thus, researchers or lecturers could or should empower other stakeholders, for example, involved NGOs or municipal administrators, taking care of long-term impact. However, the observation from a scientific point of view—including not intended side-effects and paradoxes as well as scaling effects—actually needs transdisciplinary researchers. Consequently, given research and academic structures, one dilemma, for example, simplification dilemma or scaling-aversion dilemma, is accompanied by other ones, for example, availability or observation dilemma. As the tensions of the sustainability dimensions are inherent in transdisciplinary research, scientific knowledge production should always produce knowledge on side-effects, rebounds and scenarios of blatant interdependencies and transitions. In conclusion, transdisciplinary researchers are confronted with managing diverse dilemma and second order dilemma as well as upcoming time-related dilemma, which are not met in traditional research settings.

Finally, coming back to Pennington et al., (2013) ongoing critical reflection and enabling reflective discourse within and beside the transdisciplinary processes are pivotal tasks of the organising

researchers. Especially in learning settings researchers muss include additional lecture time for reflexion and reflexive dialogue for better cognitive and affective treatment. So, their organisational ability, moderating ability and coordinating one should be stronger and better developed than in traditional research settings. Yet, as transdisciplinary settings face diverse and overlapping dilemmas and paradoxes, researchers have to cope with more than "a disorienting dilemma" (Pennington et al., 2013). In transdisciplinary settings researchers need to be open for a higher order reflexion and be able to immediately transform observations to language making tensions, dilemmas and paradoxes. In learning settings, the transdisciplinary design needs to be widened by a first step or phase addressing necessary teaching preparation (see Figure 1). Along the whole transdisciplinary research process additional teaching roles and related tensions, dilemmas or paradoxes should be addressed and reflected. Fulfilling multiple roles in transdisciplinary settings, researchers should work in groups and organise regular supervision sessions (see Bergmann et al., 2005).

7 | CONCLUSION AND OUTLOOK

Transdisciplinarity provide important impulses for the development of sustainable options for action or transformative processes of meaning and legitimation. Yet, transdisciplinary settings are accompanied by diverse tensions, dilemmas and paradoxes that need to be considered when applying transdisciplinary research approaches. The poly-contextuality needs to be moved into the centre. The quality of transdisciplinary research is strongly linked to the consciousness of the innovation paradoxes and the side-effects of ongoing interdependences when changing the real-world with the help of new knowledge and products or services. As the tensions of the sustainability dimensions are inherent in transdisciplinary research, scientific knowledge production should always produce knowledge on side-effects, rebounds and scenarios of blatant interdependencies and transitions. Moreover, the roles of the researchers can change dramatically when operating in transdisciplinary settings. They often face double or triple or even multiple roles. Especially in learning contexts, where researchers working as lecturers, have to fill in the role of a learning guide, tutor, mentor or instructor as well. This role can move into the background when researchers have the job to organise, visualise, moderate and coordinate transdisciplinary processes.

Main tasks and responsibilities that go beyond traditional research settings are among others:

1. Having and coping with more than one role at the same time;
2. Clarifying and balancing dilemmas and paradoxes while being part of dilemmas and paradoxes;
3. Vivid social skills like moderating, communicational and stress-balancing capabilities while also having content-based abilities and expert knowledge;
4. Having and enabling critical reflexion and reflexive discourse.

In total, this calls for a more circular perspective and representation of transdisciplinary research designs and process phases—taking the specific challenges of teaching context into account as well.

A future research agenda should differentiate the variety of transdisciplinary research and investigate crucial differences between funded research projects and teaching settings. In addition, the need for full joint cooperation in all phases has to be checked. Questions need to be addressed if paradoxes and dilemmas are expressed and reflected comprehensively within transdisciplinary research approaches. Or if they are rather ignored in order to feel being able to cooperate and jointly produce knowledge. Moreover, it has to be investigated how competence-based learning designs and transdisciplinary ones can be linked effectively, and what elements are not adaptable.

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