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Towards a Critical Sustainability Science? Participation of Disadvantaged Actors and Power Relations in Transdisciplinary Research

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Abstract: This paper presents the results of a meta-analysis conducted on 40 case studies of transdisciplinary research. First, it groups the cases according to the sustainability conception that is adopted in the project, distinguishing between approaches to sustainability that consider environmental protection alone, approaches that seek to find a balance between economic growth and environmental protection, and those which seek to integrate the social, environmental and economic aspects of sustainability. Next, the paper explores the extent to which the conception of sustainability adopted in the transdisciplinary project influences a series of process features in the projects. In particular, we focus on the extent to which the projects allowed for the participation of disadvantaged groups, the degree to which they accounted for and attempted to mitigate power differentials between participants, their embeddedness in longer-term dynamics and the heterogeneity of the actors piloting the projects. We also discuss the effects of these on the social learning and empowerment generated among participants. The paper finds that among the selected case studies, those with an integrated approach to sustainability more often included disadvantaged groups and acknowledged power differentials, applying a range of tools to mitigate these. Moreover, these cases also more often reported generating empowerment and social learning.

Keywords: transdisciplinarity; sustainability; sustainability science; social learning; empowerment; power

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1. Introduction

The literature on transdisciplinarity occasionally distinguishes between research conducted in different contexts, e.g., in the Global North and South [1], with a view to better identifying the transdisciplinary research methods that contribute to the empowerment of disenfranchised social groups. In this article, we propose a new distinction in which we differentiate between types of transdisciplinary (TD) research conducted according to various perspectives of sustainability, which could be relevant in both the Global North and South. Indeed, while transdisciplinary research often deals with sustainable development and is closely tied to sustainability science, the literature on transdisciplinarity rarely discusses what is understood by the term "sustainability". Meanwhile, sustainability remains a highly contested concept [2]. By conducting an in-depth literature review of forty cases of transdisciplinary research, this article distinguishes between different "faces of sustainability" (environmental, environmental-economic and integrated sustainability). We propose the hypothesis that certain design features, principles and tools applied in transdisciplinary research vary according to the conception of sustainability that is adopted in the study. More specifically, we examine the extent to which adopting certain conceptions of sustainability leads to the inclusion of marginalized actors in TD research, while acknowledging and countering the unequal power relations that may exist between stakeholder groups. We also examine the heterogeneity of the team involved in piloting the study as well as the embeddedness of the project in a long-term dynamic. We also explore the outcomes

of each case, distinguishing between the social learning and empowerment generated by the transdisciplinary research studies. The article finds that the extent to which transdisciplinary research addresses matters like participation of disadvantaged actors and power relations depends on the conception of sustainability adopted in the research.

After providing a brief introduction to transdisciplinarity and its links to sustainability science, we discuss the major conceptions and definitions of sustainability. We then present the theoretical background for our study, examining the importance of acknowledging and mitigating power relations in transdisciplinary research, of including disadvantaged actors in research processes, and of embedding these in long-term dynamics driven by heterogeneous groups of actors. We also present our conceptual framework regarding the notions of social learning and empowerment. Next, we present the methods and materials used, including the sampling strategy. We then present the results obtained from our analysis, and discuss the impact of the process features assessed on social learning and empowerment among participants of the research projects.

This paper thus seeks to answer the following research questions: What are the different conceptions (or perspectives) on sustainability that are present in transdisciplinary research? If different "clusters" of transdisciplinary research emerge according to the conceptions of sustainability, to what extent are these clusters homogeneous/heterogeneous in terms of selected process features? If different "types" of transdisciplinary research emerge according to the conceptions of sustainability, to what extent do these types differ in terms of involving marginalized groups or individuals and acknowledging, countering power differentials among stakeholders, and becoming embedded in a long-term dynamic driven by a heterogeneous research team? Finally: To what extent do these process features impact on social learning and empowerment generated among participants?

2. State of the Art

2.1. Transdisciplinary Research for Social and Environmental Transition

The current social and ecological crises call for new ways of organizing our societies. Our economic models, political systems, production patterns, management of natural resources and agricultural systems will need to undergo significant and rapid transformations in order to transition to greater sustainability and ensure the well-being of current and future generations. To accompany and guide these radical changes that will be required in many fields, a cognitive or epistemological transition is also needed.

A growing field of research examines the conditions and outcomes related to transdisciplinarity, an approach that seeks to integrate knowledge across different scientific disciplines, as well as from nonacademic actors. As one of the key principles of sustainability science [3], the aim of transdisciplinary research is specifically to resolve sustainability-related challenges by focusing on life-world problems in which (a) facts are uncertain; (b) the nature of the problems is disputed; and (c) stakes are high [4]. Under such circumstances, scholars such as Funtowicz and Ravetz [5] call for a transition from normal to post-normal science, passing from Mode I to Mode II, which "has features such as transdisciplinarity, heterogeneity, reflectivity, social accountability and context- and user-dependency". Indeed, instead of separating science from society, as postulated by Aristotle, transdisciplinarity seeks to enter "into dialogue and mutual learning with societal stakeholders", allowing science to become "part of societal processes" [4].

Despite its close conceptual link with these modes of research, transdisciplinarity goes beyond multidisciplinarity (different disciplines working in parallel on the same object of interest) and interdisciplinarity (the integration of knowledge from different scientific disciplines). Indeed, transdisciplinarity requires both interdisciplinarity and the inclusion of knowledge from nonacademic actors. It is considered a key component of sustainability science [3] seeking to conduct research in a way that enables the exploration and application of sustainable pathways [6], in view of leading the way out of the current "polycrisis" [7]. More precisely, transdisciplinary research requires the development of "a more interdisciplinary, iterative and open-ended organization of the interaction between science and

policymakers, in close collaboration with social actors and practitioners who can contribute to problem framing and ongoing assessment and revision of proposed solutions" [3]. As described by Lang et al. [8], transdisciplinary, community-based, interactive and participatory research approaches all "have in common that they focus on research collaborations among scientists from different disciplines and nonacademic stakeholders from business, government, and the civil society in order to address sustainability challenges and develop solution options".

However, this conception of transdisciplinarity is challenged from outside of the field and contested within it. Indeed, as Lang et al. [8] note, the "literature [on transdisciplinarity] is rather fragmented and dispersed, without providing good guidance to interested researchers and practitioners on what can be learned from the different approaches and what needs to be considered when planning and carrying out transdisciplinary sustainability research". Outside of the transdisciplinary community, moreover, more conventional views of science may question the field's reliability, validity and credibility [8].

2.2. The Three Faces of Sustainability in Transdisciplinary Research

Sustainability and sustainable development are essentially contested concepts [2], with a multitude of norms, values and objectives underlying various streams of environmentalism. Indeed, sustainable development has been qualified as "not defined" and "elusive" [9], "ambiguous" [10] and "theoretical" [11]. While the World Commission on Environment and Development in 1987 defined the concept of sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs", transdisciplinary researchers acknowledge that "sustainable development is strongly disputed when it comes to concrete terms and implementation" [12]. This may be, as Spangenberg [13] notes, precisely because the role of sustainability science is to "make the normative concept of sustainability operational, and the means to plan and implement adequate steps towards this end". Indeed, in this view, "sustainability science can and must provide room for different disciplines, philosophies of science and methodologies" with a common concern for "a transition of societal structures, institutions and regulation modes" (Ibidem). Spangenberg [13] also emphasizes the importance of the problem-framing phase, in which "the concept of sustainability, the values at stake, the roots of the problem and the decision-making space available" are framed. This points to the variety of conceptions of sustainability that co-exist and which must be specified at the start of a sustainability science research project.

While the literature thus acknowledges a multitude of possible conceptions of sustainability, perhaps the most widely cited definition of sustainable development remains that which simultaneously considers social, environmental and economic aspects, or, as coined in the managerial perspective of environmentalism: people, planet, profit; the triple bottom line. Transposing the above three components to a typology offered by Joan Martinez-Alier [14], one can distinguish between an environmentalism of the poor (socio-environmental perspective of sustainability), the gospel of eco-efficiency (environmental-economic perspective of sustainability) and the cult of wilderness ('purely' environmental perspective of sustainability). According to Martinez-Alier, the second of these three approaches currently drives the environmental debate. Present as a "techno-economic paradigm" [15] mirrored in the Paris Agreement and the Sustainable Development Goals (SDGs), the gospel of eco-efficiency is defined by Martinez-Alier as a "managerial science mopping up ecological degradation", a "scientific management of natural resources for permanent use", which is "concerned with the efficient conservation and use of natural resources". This form of "green capitalism" is not opposed to economic growth; instead, it calls for a dematerialization of the economy and improved eco-efficiency in order to decouple economic growth from the (over)use of natural resources. In other words, this approach does not seek to challenge the market-based status quo; instead, it relies on market mechanisms, financial incentives and technological improvements to achieve more sustainable economic growth. This is typically known as a "weak sustainability" approach, which al-

lows for the substitution of manufactured capital for natural capital [14]. Another typology which views sustainability as composed of three separate domains distinguishes between environmental stewardship, economic efficiency and social equity. Table 1 summarizes the conceptions of sustainability as understood by different scholars.

Table 1. The three "pillars" of sustainability.

Perspective	Social Sustainability	Environmental Sustainability	Economic Sustainability
Barbier 1987 [16]	People	Planet	Profit
Martinez-Alier 2002 [14]	Environmentalism of the poor	Cult of the wilderness	Gospel of eco-efficiency
Doust 2014 [17]	Social equity	Environmental stewardship	Economic efficiency

While some describe the three components (people, planet and profit) as separate "pillars" of sustainability or overlapping circles (see e.g., [18]), others analyze them as "links" in the chain of sustainability [19], bringing together two of the three components. This approach implies the existence of three additional possible combinations: economic-environmental sustainability, socio-economic sustainability and socio-environmental sustainability (Ibidem). According to Connelly [2], these represent "balances" or trade-offs between "extreme viewpoints that prioritize economic growth with no concern for environmental costs (A), environmental protection at any economic and social cost (B) and social justice with no concern for economic growth or for the environment (C)". Figure 1 below represents the extreme viewpoints and balances between the three axes, where the axis between points A and C represents positions in the "traditional political debate between the priorities of growth and equity", the axis between points A-B refers to the relative priorities between the environment and economic growth, and the final axis, B-C, representing the positions in the debate between environmental and social goals (Ibidem).

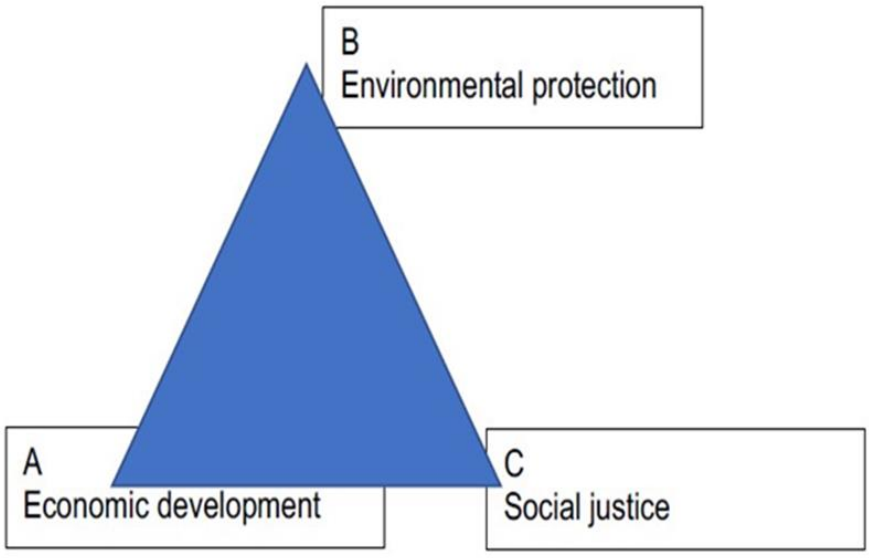

Figure 1. The "trilemma" of the sustainability pillars. Source: Connelly [2].

In this paper, we examine cases of transdisciplinary research that are concerned primarily with environmental protection (point B on the triangle), cases of transdisciplinary research that perceive sustainability as a compromise between the environment and economic growth (axis A-B) and integrated approaches to sustainability which look for a balance between economic development, environmental protection and social justice (A-B-C).

3. Theoretical Framework

In this section, we outline the theoretical framework concerning the four process features according to which we analyze the 40 selected case studies. We first examine the importance of including disadvantaged actors in transdisciplinary research and of acknowledging and countering power differentials that exist between participants of transdisciplinary research processes (Section 3.1). We then describe the importance of embedding transdisciplinary research in longer-term dynamics, driven by highly heterogeneous teams (Section 3.2). Finally, in Section 3.3, we present the outcome features that will be further discussed in Section 5 when we link the process elements to the generation of social learning and empowerment among participants.

3.1. Power Relations and Disadvantaged Actors' Groups

Global economic growth is associated with increased environmental impacts and heightened conflicts over resource use and the distribution of environmental "goods" and "bads". While political ecology scholars study these conflicts and distributions by examining the role of unequal power relations [20], the field of transition studies, which aims to understand long-term processes of transformative change towards more sustainable societies, has faced criticism for its supposed failure to sufficiently integrate issues of power, politics and agency into the theories it develops [21]. Meanwhile, the question of power is central to the transition to more equal and sustainable societies. For example, it is argued that some relatively "powerless" social groups such as indigenous people or peasants disproportionately bear the burdens and impacts of economic growth [14]. These minority actors "occupy relatively little environmental space, (. . .) manage sustainable agroforestal and agricultural systems (. . .) make prudent use of carbon sinks and reservoirs, and have livelihoods that are threatened by mines, oil wells, dams, deforestation and tree plantations (. . .)" (Ibid, p. 13). They are often engaged in exercising counter-power to environmental interventions carried out by more powerful actors such as companies, government agencies or nongovernmental organizations through different types of "resistance, adaptation or pragmatic engagement" [22]. Studying the dynamics between more and less powerful actors is therefore key to understanding and resolving social and environmental problems. As a result, the transdisciplinary processes that seek to analyze those problems may at times involve both powerful and powerless actors together, despite the risks and potential pitfalls such choices can carry.

As argued by Edmunds and Wollenberg [23], powerful stakeholders often succeed in gaining the upper hand in natural resource use in the absence of negotiations, but also when multistakeholder negotiations fail to take into account disadvantaged groups. In other words, "there is a risk of the more powerful stakeholders having greater influence on the outcomes of the participatory process that marginalized and socially disadvantaged stakeholders" [24]. While in theory, transdisciplinary research intends to involve researchers and nonacademic actors on "equal footing" [25], some research approaches and methodologies acknowledge that this claim is purely speculative, with stakeholders arriving at the research process endowed with different capacities to mobilize material sources in order to influence a decision or process (instrumental power), varying material and structural conditions (structural power) and capable of influencing the desires and beliefs of other actors (discursive power). Stakeholders benefit from different levels of material and ideational sources of power, such as financial means, access to natural and technological assets, as well as authority, legitimacy and knowledge (Ibidem). As rendered explicit by Wittmayer and Schapke [26], "power-free spaces do not exist".

For Pohl et al. [12], power differentials present in TD research processes raise the "challenge for researchers to try to prevent more powerful elite groups influencing the research process at various stages from problem framing through to dissemination of knowledge". As noted also by Barnaud and Van Paassen [24], "this concern reflects the normative agenda implicit in much [transdisciplinary research] toward empowering less powerful social actors in the knowledge production process" [12]. Indeed, insofar as

transdisciplinary research seeks to depart from "real-world" issues with the intention of solving societal challenges [8], the growing scientific community around transdisciplinary research acknowledges that researchers must engage more deeply with power and politics in research processes. This is not for purely moral reasons; instead, paying attention to power differentials among stakeholder groups is important in order to understand and prevent power structures from "hamper[ing] joint knowledge production and problem-solving" [25]. There is, in short, epistemic value in seeking to attenuate power relations between participants.

In the research approaches acknowledging different "power resources" of actors, a number of tools and methods are put forward to seek to attenuate these differences. Otherwise, according to these authors, power asymmetries outside of the research process are likely to be reproduced or increased among stakeholders within the research process [24]. In line with the political ecology perspective, in this paper we argue that including disadvantaged groups whilst acknowledging and countering the power relations that exist between them and other actors is key to advancing social and environmental justice.

3.2. Long-Term Dynamics and Heterogeneous Teams in Transdisciplinary Research

As discussed in Section 2.1, transdisciplinarity seeks to integrate knowledge across different scientific disciplines, as well as from nonacademic actors, with the aim of resolving sustainability-related challenges. Transdisciplinary research projects are often piloted by steering committees or piloting teams, who hold the responsibility (and the power) to select the participants of the project, design the methodological framework, facilitate workshops and other participatory spaces, analyze and publish the results of the project. While in many cases, these roles are taken on by academic researchers, the field of transdisciplinarity has also sought to diversify the actors present on such piloting teams. Among other reasons, a greater diversity in the teams piloting transdisciplinarity studies ensures that the knowledge types and interests of different participant groups (including local and indigenous communities) are better incorporated in the research design, that power to select participants is distributed among different stakeholders, and that leadership and ownership over the project are shared by the participants. In this way, the risk of conducting extractive research is minimized [27]. In the same way, embedding a transdisciplinary research project in a longer-term dynamic helps to build trust and mutual learning among the participants of the project.

3.3. Social Learning and Empowerment

According the Mitchell et al. [28], transdisciplinary research aims to produce three outcomes: (1) an improvement within the 'situation' or field of inquiry; (2) the generation of relevant stocks and flows of knowledge, including scholarly knowledge and other societal knowledge forms, and making those insights accessible and meaningful to researchers, participants and beneficiaries; and (3) mutual and transformational learning by researchers and research participants to increase the likelihood of persistent change. Whilst the first two may be diffuse across time and space, making it difficult to assess whether a TD research project effectively produced improvements in the problem situation and generated stocks and flows of knowledge, the social learning component is possible to evaluate in the immediate aftermath once a TD project has been concluded.

However, the "range and mix of concepts implicitly associated with social learning has greatly reduced the applicability of the concept" [29]. Moreover, few studies have sought to explicitly measure the social learning generated in collective projects, including in transdisciplinary research (for examples see [30,31]). For Van der Wal et al. [32], who assess its incidence in collaborative governance arrangements, social learning is necessary because it "creates the basis for integrated solutions that require collective support and/or concerted action of multiple stakeholders (Roeling 2002) and its potential role as a governance mechanism in natural resource management and climate adaptation has been frequently highlighted over the past decade". Reed et al. [29] provide a detailed discussion of social

learning, acknowledging that it "is increasingly becoming a normative goal in natural resource management (...) and that this is "linked to earlier shifts toward adaptive management and stakeholder engagement as a means to cope with complexity and the resultant uncertainty with which managers are faced. It is argued that those involved in the management of social-ecological systems may learn and therefore enhance their adaptive capacity through their involvement in decision making".

In contrast to early definitions of social learning, which conceptualized it simply as "individual learning that takes place in a social context as in influence by social norms, e.g., by imitating role models" [33], this article understands the term as proposed by Reed et al. [29]: to be qualified as social learning, there must be a demonstrated change in understanding that has taken place among individuals involved in the transdisciplinary process. This can be either at a "surface level" (i.e., through a recall of new information) or at a deeper level (e.g., a change in attitudes, worldviews or epistemological beliefs).

The concept of social learning as defined in parts of the literature evoked above may be interpreted as claiming that there is a truth to be discovered by the members of a collective research process, and therefore that a high level of social learning should lead to a convergence in the knowledge, goals, values, norms and beliefs among participants [32]. In this paper, we consider instead that collaborative, transdisciplinary research processes create spaces for opening participants to new ideas and exploring possibilities that were not previously imagined by the group and its members. In this sense, transdisciplinary research can be seen as a dialogic process, which does not necessarily lead to closure and definitive answers. Instead, it can provide "a relational space that both enlarges the potential for transformation and lays the pathways through which transformation may be achieved" [34]. In this way, transdisciplinary research processes may contribute to the generation of "new mental models, ideas, and practices that can help shift social-ecological systems onto more desirable pathways" [35]. While in this paper we consider social learning as an outcome, it is also indeed a process [29] by which such models, ideas and practices can be developed and cross-pollinated in the transdisciplinary transformative space, and thereafter diffused among its participants in their communities of practice.

Based on the definition that we adopt for social learning, empowerment is an associated concept in the sense that individuals or groups who become empowered through a collaborative process undergo a change in which their capacity to act becomes strengthened. This enhanced capacity to act has both subjective and objective components. Scholars such as Arnstein [36] and Kruetli et al. [37] place empowerment as the final step on the continuum of participation, which includes also information, consultation and collaboration. Empowerment is understood as situations in which the public is given the authority to decide, or is involved in decision-taking [37]. This is the processual vision of empowerment, in which part of the power typically conferred to researchers becomes shared with stakeholders in transdisciplinary processes, including the power to formulate research questions, to analyze and synthesize data, and to publish and present results [38]. In this paper, we understand empowerment rather as an outcome of a research process. We study its occurrence by examining whether at the end of a transdisciplinary project, stakeholders' capacity to act and to improve their own situation [27] was enhanced or remained stable. While sometimes (though not always) transdisciplinary processes explicitly aim for this kind of empowerment, Brandt et al. [39] note that they rarely achieve this objective.

4. Materials and Methods

In this section, we present four types of process features which, according to our theoretical framework, may contribute to the three aspects discussed above: balancing of power relations, integration of heterogeneous knowledge sources and empowerment. These features will serve as the evaluation grid to assess the differences amongst the types of sustainability research in terms of their sustainability approaches.

The first process feature (Criterion 1) according to which we assessed the case studies is the extent to which disadvantaged groups are included to partake in transdisciplinary

research processes. We predict that transdisciplinary research based on the purely 'environmental' or economic perspectives, or a mix of both, (environmental-economic perspective) will tend to include a wide range of actors who are considered to participate on equal footing among one another. By contrast, we anticipate that transdisciplinary research following a more "integrated" approach to sustainability is likely to be preoccupied with capacity-building and empowerment, involving actors that are likely to be weaker parties of a process but essential to bringing about transformative change. For instance, in pro-poor transformative transdisciplinary research, Marshall et al. [34] note that "pro-poor actors are (. . .) central to alliance building and will include researchers, activists, nongovernmental organization, and community groups with a social justice emphasis who aim to work on behalf of the interests of the poor". In this paper, we define disadvantaged groups as those "with limited power to influence decisions in multistakeholder settings", with their power limited "by their social status, their representation in public for a or their negotiating capacities" [23]. This definition includes actors that are poor, marginalized or discriminated against.

Secondly, we explore the extent to which the transdisciplinary research projects are piloted by a heterogeneous team (Criterion 2), i.e., one that is not composed solely of researchers nor of one type of stakeholder group. This design feature ensures that a variety of viewpoints are represented in strategic decisions regarding the research process, including the perspectives of "'real world actors' who have experience, expertise, or any other relevant 'stake' in the problem constellation pre-identified for the research project'" [8]. This, in turn, offers the possibility to collaboratively frame and define the sustainability problem, enhances the capabilities and interest in participation, encourages a balanced ownership of the problem, and increases the legitimacy of the research team [8,34].

Thirdly, we analyze whether the transdisciplinary research projects are embedded in a longer-term process, (Criterion 3) i.e., whether there is a prior phase or the results of the project become integrated in existing programs [40], carried out by actors engaged in the community in the long-run. Along with Suni et al. [41] we consider that this embeddedness helps to ensure that the results of the transdisciplinary research are perennial and can be re-integrated into societal practice, responding to long-term sustainability goals. In this way, we predict that transdisciplinary research conducted from an integrated perspective on sustainability will be more likely to be integrated in a long-term dynamic, while transdisciplinary research based on environmental stewardship, economic efficiency perspectives or both will rather be concentrated on a shorter period of time and focused on more immediate results.

Finally, we explore whether the tools used and processes followed acknowledge and seek to counter the unequal power relations of participants and groups in the research team (Criterion 4). Here, we predict that adopting an integrated approach to sustainability implies acknowledging the power relations that exist between different stakeholder groups. According to Pohl et al. [12], power in transdisciplinary research is the "ability and the resources to negotiate and adapt interests during the process of knowledge co-production". This design feature is related to acknowledging and countering existing power differences to ensure that inequality in power outside of the research process is not reproduced within it [24]. We predict that that transdisciplinary research conducted from an economic or environmental perspective will be less likely to acknowledge and counter existing power relations than transdisciplinary research with an "integrated approach" to sustainability.

To determine whether there exist specific types of transdisciplinary research pertaining to the different sustainability perspectives, we selected a sample of transdisciplinary case studies broadly dealing with questions of sustainability. First, we screened four journals (Ecological Economics, Environmental Science & Policy, The European Journal of Operational Research, and Ecology & Society) for article published between 2010 and 2020 using the following three keywords: "transdisciplinarity"; "knowledge co-production" and "participatory process". We screened the results for case studies (excluding literature reviews or large-N case studies, as well as theoretical articles) of transdisciplinary research.

In some cases, participatory resource management case studies were also retained, provided that the focus of the processes was on knowledge creation, and not on stakeholder-based resource management alone.

The chosen method is an instance of a "medium-N" sample, drawn from a larger sample, which allows an in depth and "thick" analysis of each of the cases in relation to a complex problem with a set of interdependent qualitative variables. In this case, we pre-analyzed over 50 papers and kept a final sample of 27 (N = 40, as some papers presented several cases). This sample size is typical for the sample size in systematic qualitative comparative analyses (for a discussion on the sample size, see e.g., "Configurational Comparative Methods" by Rihoux and Ragin [42].

The cases were categorized according to the conception of sustainability dominant in studies, as defined in Section 2. The selected cases are listed in Tables 2–4, where each table presents the cases analyzed according to the conception of sustainability adopted in the respective papers.

After selecting the case studies and verifying that each of them could be characterized as transdisciplinary research, we screened each case and analyzed it according the main criteria outlined above: the inclusion of disadvantaged groups in the TD project, the heterogeneity of the research team piloting the study, the embeddedness of the project in a longer-term dynamic and the mobilization of tools to acknowledge and counter power relations within the TD process. For each criterion, we used a scale ranging from 1 (Low) to 5 (High). Using the criteria provided in Table S1 (in Supplementary Materials), we coded each case according to each of the criteria, then computing the mean scores for each cluster. The results of the analysis are presented in the following section.

Table 2. Cases included in the environmental sustainability cluster.

Author(s) and Date	Sustainability Challenge Studied
Carolus et al. 2018 [43]	Improving water quality in the Helge River catchment in Sweden
Carolus et al. 2018 [43]	Improving water quality in the Berze River catchment in Latvia
Schonenberg et al. 2017 [44]	Analysis of future land-use trajectories
Priess and Hauck 2014 [45]	Land use in Central Germany
Franzeskaki and Kabisch 2016 [46]	Strategic urban environmental governance in Berlin
Franzeskaki and Kabisch 2016 [46]	Strategic urban environmental governance in Rotterdam
Serrao-Neumann et al. 2020 [47]	Climate change adaptation in six Brazilian cities
Serrao-Neumann et al. 2020 [47], Serrao-Neumann et al. 2019 [48]	Climate change adaptation in Australian natural resource management
Burkhardt-Holm and Sehnder 2018 [49]; Burkhardt-Holm in Hirsch-Hadorn et al. 2008 [50]	Identification of causes of fish catch decline and proposals for remedial measures
Ceccato et al. 2011 [51]	Identification and exploration of the potential of adaptation strategies to cope with flood risk in mountain areas
Ceccato et al. 2011 [51]	Identification and exploration of the potential of adaptation strategies to cope with flood risk in mountain areas

Table 3. Cases included in the "environment-economic" sustainability cluster.

Author(s) and Date	Sustainability Challenge Studied
Saarikoski et al. 2019 [52]	Conflict between extracting vs. preserving peat in Finland due to its multiple ecosystem services
Trutnevyte et al. 2012 [53]; Trutnevyte et al. 2011 [54]	The future energy system in a small Swiss community
Siebenhuner 2018 [55]	Launching initiatives to increase the resilience to climate change
Arkema et al. 2019 [56]; Verutes et al. 2017 [57]	Developing an integrated coastal zone management plan in Belize incorporating the management of the Caribbean spiny lobster
Arkema et al. 2019 [56]	Integration of spiny lobster management into the sustainable development master plan in the Bahamas
Brand et al. 2013 [58]	Challenges and the future development of mountain regions facing glonal change (land use measures)
Puente-Rodriguez et al. 2016 [59]; Puente Rodriguez et al. 2015 [60]	Environmental and coastal zone management
McKee et al. 2015 [61]	Identification of multiple future transition pathways towards sustainable agriculture at the regional level in Scotland
McKee et al. 2015 [61]	Identification of multiple future transition pathways towards sustainable agriculture at the regional level in Portugal
Baudry et al. 2018 [62]	Assessing French stakeholders' support for different biofuel options by 2030
McKenna et al. 2018 [63]	Developing energy alternatives in small-town Germany

Table 4. Cases included in the "integrated" sustainability cluster.

Author(s) and Date	Sustainability Challenge Studied
Conde 2014 [64]	Environmental and human health impacts of uranium mining in Niger
Conde 2014 [64]	Environmental and human health impacts of uranium mining in Namibia
Marshall et al. 2018 [34]	Periurban environmental degradation and its effects on food safety, human health and livelihoods
Marshall et al. 2018 [34]	Resettlement of urban slum populations to periurban areas and subsequent cholera outbreak
Ruiz-Mallen et al. 2015 [65]	Exploring options for adapting to social-ecological changes while protecting biodiversity and ecosystem services in Bolivia
Ruiz-Mallen et al. 2015 [65]	Exploring options for adapting to social-ecological changes while protecting biodiversity and ecosystem services in Mexico
Galafassi et al. 2018 [66]	Interactions between poverty and coastal ecosystems in the Mombasa and Kwale districts in Southern Kenya
Galafassi et al. 2018 [66]	Interactions between poverty and coastal ecosystems in Mozambique
Athayde et al. 2017 [67]	Erosion of artistic knowledge among men and women, and environmental constraints linked to the availablity and management of natural resources used in basketry weaving
Masterson et al. 2018 [68]	Community-based conservation and human well-being in coastal Kenya
Masterson et al. 2018 [68]	Experiences of and responses to declining subsistence agriculture and continued labor migration in South Africa
Castellanos et al. 2012 [69]	Livelihood strategies of coffee growers in Mesoamerica facing multiple stressors of economic and physical nature
Matuk et al. 2020 [70]	Policies for supporting indigenous peoples and local communities in maintaining their knowledge and contributions to biodiversity

5. Results

The outcomes of the analysis show that differentiating among the case studies according to the conception of sustainability adopted in the research papers allows to identify several patterns. Firstly, as shown in the table above (see Materials and Methods), the sampling strategy led to a selection of a nearly equivalent number of cases based on the "purely" environmental conception of sustainability, environmental-economic sustainability and the "integrated" approach to sustainability. Second, these three major clusters present certain characteristics, making them each internally homogeneous to a certain extent.

5.1. The "First Face" of Sustainability: The Environmental Cluster

The first main cluster examined in this paper relates to "purely" environmental sustainability. In these cases, the sustainability challenges that were explored related to issues such as water quality [43], land use [44,45], environmental governance [46] and natural resource management [49], as well as climate change adaptation [47,51]. Whilst these challenges also clearly involve both social and economic considerations, the perspective adopted in these cases was largely environmental and only marginally took into account trade-offs with these additional criteria.

Of the 11 "purely" environmental case studies, 100% scored a 2 or below (Low to Medium, or Low) on the inclusion of marginalized, discriminated or poor groups; i.e., none received a Medium, Medium to High or High score on this criterion. The average score for this criterion was low: only 1.64. Indeed, most of the cases did not include any disadvantaged groups. In some cases [43,44], nongovernmental organizations or private sector organizations such as farmers' associations were involved in the research process, but none of the projects included individual citizens nor organizations of marginalized, discriminated or poor groups.

Similarly, 100% cases of purely "environmental" transdisciplinary research scored a two or below (Low to Medium or Low) on the acknowledgment and countering of existing power relations, with an average score of 1.18. Power dynamics were not mentioned in the environmental case studies, and only an ex-post analysis in the cases presented in Ceccato et al. [51] offers a reflection on the lack of obstacles to equal participation: "From the evaluation questionnaires collected at the end of the events, we had no evidence of problems concerning the opportunities to freely and equally express opinions, possible biases, or about the process being guided by a dominant discourse, which may delegitimize some of the stakeholders only because they do not subscribe to a preliminarily defined agenda". Moreover, Priess and Hauck [45] noted several differences according to stakeholder groups, but made no links to power dynamics.

Concerning the heterogeneity of the project teams, eight of the eleven environmental cases received a Low score, indicating that a large majority of the research projects were piloted by academic researchers without the input of other stakeholders. Only in the cases presented in Serrao-Neumann et al. [47] and Burkhardt-Holm and Sehnder [49] did the research consortia involve nonacademic actors such as local practitioners, government agencies or natural resource management organizations.

5.2. The "Second Face" of Sustainability: The Environmental-Economic Cluster

The cases discussed in the second cluster (environmental-economic cases) deal with issues that combine an environmental vision of sustainability with economic constraints. For instance, one study [52] discusses the trade-offs between peat preservation and peat extraction in Finland. Others explore future energy systems, development of coastal zone management or sustainable agriculture, as well as land use measures, each time simultaneously striving to satisfy environmental conditions whilst acknowledging the need for economic viability.

Among the 11 environmental-economic case studies, all (100%) scored a three or below (Medium, Low to Medium, or Low) on the inclusion of marginalized, discriminated or poor groups, with none scoring a High or a Medium to High. The cases which scored

the highest on this criterion [56,59,61] tended to include organized interests of potentially disadvantaged groups, including nongovernmental organizations, members of civil society, or representatives of indigenous groups. The average score for this criterion in the environmental-economic sustainability cluster was 2.45, lower than the overall average for all of the case studies combined (3.23).

Moreover, 10 of 11 of cases in this cluster received a score of two or below (Low to Medium or Low) on the acknowledgment and countering of existing power relations, with none receiving a score of 4 (Medium to High) or 5 (High). The average score obtained for this criterion was 1.55. In some cases, differences among stakeholder groups were acknowledged, though the link was rarely made to power dynamics. For example, in Saarikoski et al. [52] the project team conducted a stakeholder analysis, mapping actors according to their influence and interest, but the methodology did not take the results of the analysis into account, nor was power explicitly mentioned. In other cases, differences were assumed away for the purposes of the research. In the case study conducted by Arkema et al. [56], for example, it is noted that "ecosystem service beneficiaries were assumed to be uniform across the study area in the absence of information to properly disaggregate by demographic or beneficiary type, limiting what can be said about the environmental justice of the zoning scheme" [57]. In several cases (e.g., [53,60,62,63]) power is simply not mentioned. However, research teams in some of the case studies paid attention to similar features such as "good facilitation . . . to resolve conflicts and retain stakeholder involvement in the process" [56], to "building trust" between the actors and the facilitation team [60] and ensuring the "involvement of all stakeholders on an equal footing" [49], as well as "rebalanc[ing] the power distribution within the participatory process because of the authority attributed to scientific knowledge" [61].

Concerning the two additional criteria, no clear pattern emerges. However, it should be noted that for the heterogeneity of actors involved in the piloting of the project, this cluster obtained slightly above-average results (3.00 compared with an average of 2.80 across all case studies). Regarding the scale of the projects identified, the environmental-economic sustainability cluster had seven of 11 cases dedicated to studying phenomena or issues on a national level, with only two cases of transdisciplinary research conducted at the local level, and two at the national level.

5.3. The Third Face: Integrated Sustainability

The 13 cases discussed in the cluster on integrated sustainability relate to transdisciplinary research processes that examined sustainability challenges and adaptation options related to issues such as the impact of uranium mining on human health and the environment; environmental degradation and its effects on human health and livelihoods and the protection of biodiversity by communities. These cases of transdisciplinary research were all conducted in the global South (Niger and Namibia, India, Bolivia and Mexico, Kenya, Mozambique, South Africa and Central and South America), and seem to match closely with Martinez-Alier's conception of an "environmentalism of the poor".

Among the 13 socio-environmental case studies, 11 (84.6%) scored a four or above (Medium to High or High) on the criteria of including groups that were marginalized, discriminated against or living in poverty. The lowest score received for this criterion was a 3 (Medium), and only two cases received this score. The average score received by the case studies in this cluster for the inclusion of marginalized actors was 4.54. Disadvantaged actors included, for example, workers in the field of uranium mining concerned about their health and that of their surroundings; farmers and marginalized communities such as landless men and women, residents of impoverished neighborhoods, fishermen, etc. In some cases, the disadvantaged groups were represented by nongovernmental organizations (NGOs) [64]; in other cases, the participants in the research were groups of individual citizens [68,70].

Concerning the acknowledgment and countering of existing power relations, 69.2% of cases scored a 4 or above (Medium to High or High). Four cases scored below a

Medium (Low to Medium), with the average score reaching 3.85. A diversity of approaches were applied to counter the power relations among different actor groups. For example, Conde [64] sought to avoid cooptation of the research by scientific stakeholders. Similarly, in Marshall et al. [34] (case 3a), an ongoing dialogue was opened about power relations and the use of technical language was disallowed in order to counter power dynamics in the production of knowledge and the framing of the research questions. Other techniques used included creating separate focus group discussions to avoid reproducing socio-economic inequalities present in communities [65], using break-out groups and balancing gender and space [66], and mobilizing photovoice [68] as a forum for engagement and learning, facilitating the expression of opinions, knowledge and experiences. In many cases, the acknowledgement of existing power differences early on in the process allowed the research team to pay particularly close attention to the group's dynamics. For example, in Galafassi et al. [66], observers took notes in plenary and break-out sessions in order to keep track of content produced, but also of "impressions of how discussions evolved in each group; for instance, whether there were conflicts, or if specific participants were dominant, motivated, or disengaged".

In two cases, however, the results are more surprising [65,67]. While both case studies are highly inclusive of disadvantaged groups, both also obtain Low scores concerning the acknowledgement and mitigation of existing power relations within the research project. In the former case, power is an important issue addressed in the article; however, its focus is mainly on power outside of the research process. Inside the research process, power differences are not explicitly mentioned or acknowledged, although the authors observe a limited engagement of individuals from the community in the focus groups. The authors consider that "such limited engagement is explained by cultural factors, such as young men and women's unfamiliarity to talk in public meetings". In the latter case, power relations between actor groups are not explicitly mentioned nor countered, although concepts such as "epistemic injustice" and "subjugation and misrepresentation of indigenous knowledge by academics" are evoked. This, once again, shows a concern for power dynamics even though specific tools are not described that seek to mitigate these in the process.

Concerning the heterogeneity of stakeholders present in the team piloting the research, no clear pattern can be discerned. The cases obtained scores ranging across the scale from 1 to 5, with a mean score of 2.92 in this cluster. Concerning the projects' embeddedness in longer-term dynamics, a majority of transdisciplinary research projects in the integrated sustainability cluster scored High on this criterion; however, four projects received a 2 (Low to Medium). Therefore, no clear conclusions can be reached about these two criteria. Finally, concerning the last criterion, which examines the scale of the projects identified, nearly all (twelve) of the transdisciplinary research projects in the integrated sustainability cluster were dedicated to studying local phenomena or resolving local issues.

5.4. Additional Clusters

Finally, whilst benefitting from a smaller sample size, the cluster related to "social" sustainability presented highly homogeneous results for the first criterion: 100% of the four cases in this category scored a 5 (High) on the inclusion of marginalized, discriminated or poor groups. In this cluster, the main focus of the cases was turned towards disadvantaged groups: indigenous stakeholders, persons with disabilities living in slum neighborhoods, drug users, bonded laborers, and youth in poor suburbs. Results for the acknowledgment and countering of existing power relations were more mixed, with 25% of cases scoring a 3 (Medium), 50% scoring a 4 (Medium to High), and 25% scoring a 5 (High). In one case [71], power was explicitly mentioned, with empowerment of participants defined as a key objective of the research project, however there is no mention of design features, tools or methods put in place to address power differentials. Conversely, in other cases [72] power mentioned only marginally, but a multitude of tools were deployed that are likely to attenuate differences in power resources (e.g., parallel action research groups, work in pairs, collective analysis, facilitation, surveys based on pictorial representations to take

into consideration that some respondents were illiterate, etc.). On another criterion—the heterogeneity of actors involved in piloting the research project—this cluster scored highly across all cases (100% of cases achieving a five). Indeed, each of the research projects was the result of a highly collaborative arrangement between scientists and NGOs [73], local communities [71] and practitioners [67]. The "social" sustainability cases were each conducted at different levels: local, regional, national and international. It should be noted that the small sample size (N = 5) of the social sustainability cluster makes it difficult to draw any precise conclusions. Nonetheless, our findings suggest that the link between social sustainability and the inclusion of disadvantaged groups, as well as the use of methods and tools for attenuating power differences (whether explicitly or not) deserves attention in future research.

Concerning the additional two clusters, i.e., case studies representing the economic or socio-economic conceptions of sustainability, the sample size of each cluster was unfortunately too small to draw any major observations.

6. Discussion

The literature on transdisciplinarity finds that the design features applied to participatory research has an impact on outcomes (see e.g., [30]). Therefore, while the transdisciplinary stream stops short of offering specific guidelines on the methods and tools to be used, it acknowledges that these play a significant role in the process and outcomes of the research. Table 5 summarizes the results of the process and outcome criteria studied in the meta-analysis presented in this paper. Scores for criteria 1–4 were attributed based on the indicators included in Table S1 in Supplementary Materials. Concerning social learning and empowerment, when more than two-thirds of cases in a given cluster scored highly on these aspects, we considered the result as "HIGH". If between one-half and two-thirds scored highly, the criterion was ranked as "MEDIUM". If less than half of cases scored highly on social learning or empowerment or where these criteria were not reported on, the criterion was ranked as "LOW".

Table 5. Average results by criteria for each cluster.

Cluster (Approach to Sustainability)	Number of Cases	Average for the Criterion				Social Learning	Empower-Ment
		1	2	3	4		
Environmental	11	1.64	1.64	3.27	1.18	LOW	LOW
Environmental-economic	11	2.45	3.00	3.18	1.55	MEDIUM	LOW
Integrated	13	4.54	2.92	4.00	3.85	MEDIUM	HIGH
ALL	35	3.23	2.80	3.55	2.50	MEDIUM	MEDIUM

Legend: Criterion 1 = Extent of inclusion of disadvantaged groups in the research process; 2 = Extent of heterogeneity in the research group piloting the study; 3 = Extent of embeddedness of the research process in a longer-term dynamic; 4 = Extent to which power relations between actors are acknowledged and countered in the research process.

According to this snapshot of the results, it seems that when the cases achieved a higher-than-average score on the process features relating to the inclusion of disadvantaged groups in the research process and on the acknowledgement and countering of power relations, higher than average empowerment outcomes were achieved.

6.1. Empowering Disadvantaged Actors and Generating Social Learning

In the cluster with an integrated approach to sustainability, each of the criteria received a score above the average obtained across all case studies. The first and fourth criteria obtained particularly high scores, indicating that integrated approaches to sustainability strongly involved disadvantaged groups and paid close attention to power differentials between participants, applying various tools and methods to attenuate these. For example, in one study [68], the use of photovoice with communities in Kenya and South Africa helped to overcome cultural and social barriers to communication and facilitated the engagement

of individuals (particularly women) who otherwise would not have participated, effectively empowering them. In another case [70], the inclusion of disadvantaged groups (indigenous peoples and local communities) and a focus on attenuating power differences between the plurality of knowledge forms present in the project also led to the empowerment of actors, with participants becoming knowledge agents and disseminating the results of the research process to community members who were not involved. In yet another study [64], a relatively strong inclusion of disadvantaged groups (Medium to High) and a strong attention paid to power differentials—particularly between the disadvantaged actors and the scientists collaborating with them—led to high levels of empowerment, with local organizations and individuals becoming political actors, acquiring visibility, knowledge and skills, and raising their voices against multinational companies involved in uranium mining.

Conversely, slightly lower scores attributed to the first and fourth criteria led to the "persistence of dominant narratives" [66] within the research process, suggesting low empowerment of the disadvantaged groups involved. Similarly, two cases [65] who were preoccupied with power relations to little (Low) or some (Medium) extent did not report on the empowerment of marginalized actors at all, despite the fact that they were highly involved in the research. Despite the missing data, we can infer that that low levels of empowerment were also obtained in these studies. These cases obtained relatively low scores on the heterogeneity of the group piloting the studies (Low) as well as on the embeddedness of the research process in longer-term dynamics (Low to Medium) which may explain the weak outcomes on the empowerment variable.

The results in the integrated sustainability approach confirm that there is a link between the environmentalism of the poor conception of sustainability and transdisciplinarity that takes into account marginalized communities and actors. Indeed, both sustainability and transdisciplinarity are related to the field of ecological economics. It acknowledges the weak commensurability of values, and proposes methodological pluralism to overcome reductionist approaches like cost-benefit analyses. As such, it refuses to base decision-making on a single discipline, calling for a "post-normal" science that would "take into account the contradictions between disciplines" whilst also including the knowledge of citizens, who challenge certified experts. This is the very essence of transdisciplinarity. Indeed, one scholar notes that research involving "collaborations between traditionally historically marginalized communities and professionals can be classified as part of the environmental justice movement, as they demand an end to social and economic policies that subject excluded and poor communities to environmental hazards affecting their health (. . .)" [64].

In the environmental-economic cluster, each of the criteria received below-average scores, with the notable exception of the heterogeneity of actors piloting the project, which scored above the overall average (3.00 compared to 2.80). Concerning the empowerment of participants, the environmental-economic cluster achieved weak results. We argue that this is linked to the low level of inclusion of disadvantaged groups and the (partial) disregard for power relations between actors' groups. Two examples serve to elucidate this link. First, the case which scored the highest on these two criteria [61], obtaining a 3 (Medium) level for both, also reported on the empowerment of the participants. This study noted that in both Portugal and Scotland, the project for identifying pathways towards sustainable agriculture at the regional level led participants to explicitly express their desire to continue the discussion and to develop further research on this topic. Another project which scored relatively high on both criteria (3 and 2) reported that repeated engagement with stakeholders made them feel more committed to the process and optimistic about the potential for positive outcomes [56]. Other projects that scored less highly on these criteria did not report on empowerment.

Similarly, in the environmental sustainability cluster, the cases scored below-average on all four criteria, and achieved low levels of empowerment. With the exception of one out of the eleven case studies, none of the articles mentioned any empowerment of participants

involved, making it difficult to draw any specific conclusions about the process criteria related to the inclusion of disadvantaged groups and acknowledgement of power relations.

Based on the discussion above, an important question emerges. Why are transdisciplinary processes with an environmental or environmental-economic conception of sustainability hesitant to involve disadvantaged groups and to consider and counter power relations embedded in their processes? We offer three possible reasons for this reluctance. First, as noted by Edmunds and Wollenberg [23]: "Institutions may be able to assure a high degree of communicative rationality in setting where the power to influence (...) is relatively well-balanced among stakeholders, and where cultural and social heterogeneity is low". This explains why some studies may not pay considerable attention to power differentials: as disadvantaged groups are not included to begin with, cultural and social heterogeneity may be low. Conversely, in TD research projects with an integrated approach to sustainability, disadvantaged groups are one of the key, if not the key, stakeholders involved, which requires specific methodological and design features to take into account the high heterogeneity of actors present in the participatory process.

Second, in some of the cases of environmental-economic TD research, disadvantaged groups are involved to a medium extent, receiving a score of 3 on this criterion. Meanwhile, in those cases, power relations are not always considered nor countered with the same intensity (as measured by the score). This may be because some multistakeholder processes, including transdisciplinary research projects, consider that a "neutral or objective space for negotiation can and should be created", (Ibidem) and thus power differentials are intentionally overlooked, with good communication pointed out as the key to achieving consensus. Drawing on the Habermasian ideal of communicative rationality, such projects may consider that placing all relevant actors around a table and providing them with equal treatment creates a space for different interests to be heard and considered.

Third, it may be possible that disadvantaged groups are consciously or intentionally left out of the processes in environmental or environmental-economic TD research, given that their inclusion requires specific design features and practical arrangements. Indeed, considering that the results of facilitated sessions in "supposedly apolitical fora (...) have often been disastrous", organizers of TD research projects may be reluctant to involve highly heterogeneous actors.

Based on the discussion above, therefore, it should be noted that not all research projects are destined to involve highly heterogeneous actor groups nor to work specifically with disadvantaged groups, taking into account the power asymmetries that impact the relationships between participants. This depends partly on the subject area, and, as this article shows, on the conception of sustainability that is adopted in the problem framing phase of the research [13]. For example, it would not be surprising that a paper dealing with a topic like the relationship between species diversity and ecosystem resilience would pay less attention to disadvantaged groups and power relations.

However, for future transdisciplinary projects that do seek to include disadvantaged groups and to counter the power relations that exist among them, research projects related to the integrated vision of sustainability may provide insights on the methods, tools and approaches that can be used. Among postures and approaches seeking explicitly to influence power asymmetries, beyond those presented in the case studies of this meta-analysis, the "critical companion" posture and the "Merging Knowledge" research approach are worth pointing out. The first, developed by Barnaud and colleagues, "is a non-neutral posture that recognizes the necessity to take into account power asymmetries to avoid the risk of increasing initial asymmetries". It seeks to make the underlying assumptions and objectives explicit to participants so that stakeholders can accept their legitimacy or reject them and refuse, for instance, to participate in the process. It pays attention to power dynamics and strategically selects stakeholders, empowering weaker actors while focusing on strong actors and convincing them to take part in dialogue.

The second is a research approach developed by the international movement ATD Fourth World [74]. It seeks specifically to guide transdisciplinary poverty research with

the ultimate aim of eradicating poverty. In the approach, knowledge hailing from three sources is combined in order to obtain a "more complete picture" of poverty, its causes and consequences: experiential knowledge of persons experiencing poverty is merged with the action-based knowledge of persons and professionals working alongside them and the theoretical knowledge of academics. By introducing specific tools and methods, such as the use of peer groups and spokespersons, the approach seeks to attenuate power differentials that exist outside of the process between the three groups. Research conducting using the "Merging Knowledge" approach tends to involve a heterogeneous group of actors in the team piloting the study; moreover, the involvement of nongovernmental organizations on the ground (including but not limited to ATD Fourth World) ensures that the research projects are embedded in long-term dynamics. In a past Merging Knowledge project, collective empowerment was found to have been generated among participants [31].

The results of the meta-analysis concerning social learning are more ambiguous. Indeed, there is no clear link between the process criteria and the social learning reported by the authors of the papers. One article [61] in the environmental-economic cluster specifically evaluated the social learning generated by the process in two cases (22a and 22b), concluding that "[e]vidence of social learning is demonstrated in the exchange of information between participants, the establishment of new contacts, acknowledgement that participants received new information and changed their understanding of the topic (. . .) Furthermore, researchers reported that the clarification of questions between stakeholder participants lead to the alteration of individual participant discourses, again indicating social learning". In another case (the Fischnetz project) which adopted an environmental perspective of sustainability, mutual learning was considered to be successful, with knowledge transfer and exchange of ideas and opinions contributing to a better understanding among stakeholders [49]. Finally, one case with an integrated vision of sustainability [71] also reported on the transformational effects of an educational peace program developed in Colombia. Some cases (e.g., [52,66]) reported achieving lower levels of social learning or "double-loop learning" as compared with the expectations for the projects. From these examples, it seems that the cases with lower social learning have a common characteristic: they scored quite low on the heterogeneity of the actors piloting the project. By contrast, those which achieved positive results in terms of social learning scored highly on this variable. However, beyond this observation, the patterns are tentative and therefore further research is required to test the importance of all four variables on social learning outcomes.

6.2. Limitations

The analysis of the 40 cases of transdisciplinary research are based on one or several articles published on the individual case studies. This means that the coding and analysis of these cases fully depends on the information shared in those articles. Indeed, if an article omitted information about a variable—that was nonetheless considered in the research design—we did not triangulate the missing data with another source, such as interviews. It is important to note, therefore, that the results say more about what the publications reported about the given cases than what actually occurred in the transdisciplinary process.

This brings us to another limitation. The articles presenting the cases were mainly written by academic researchers, who either led the transdisciplinary projects they reported on, were close to these processes, or investigated them ex-post through the use of e.g., interviews and secondary sources. As such, the processes and outcomes are described through the lenses of those researchers, and only rarely from the perspective of practitioners; much less from the viewpoints of participants from disadvantaged groups. The results should therefore be interpreted with caution, and additional research based on the perspectives of nonacademic actors is needed to confirm these preliminary findings.

Finally, the relatively small sample size within each cluster point to the need for further research to be conducted on a larger number of cases. The findings discussed above should be understood as initial findings that pave the way for additional work on the relationship

between design features of TD research and the conception of sustainability adopted in the cases.

7. Conclusions

The field of transdisciplinary research has gained considerable traction and attention over the past several years. Whilst this current of research deals primarily with complex sustainability problems, few papers explicitly discuss or define what is understood by "sustainability". In this article, we have shown that various conceptions of this term coexist implicitly in transdisciplinary research: some TD research projects focus specifically on the environmental "arm" of the sustainability triangle; others seek to balance environmental protection with economic growth; still others add on the social dimension of sustainability, seeking to integrate the three components present in the classical tripartite model of sustainability.

As we have shown, the perspective of sustainability that is adopted in TD research is not inconsequential. Indeed, by conducting a literature review of 40 cases of transdisciplinary research projects, we have traced a relationship between the conception of sustainability that is adopted and specific features that are introduced in the research design. In particular, we have examined the extent to which the cases within the different clusters (1) include disadvantaged actors in the research; (2) are piloted by heterogeneous teams; (3) are embedded in long-term dynamics; and (4) acknowledge and mitigate power relations between participants. Moreover, we have examined the links between these process features and social learning and empowerment outcomes.

Our findings show that the clusters adopting environmental or environmental-economic conceptions of sustainability are less likely to empower participants. We link this with the relatively scarce inclusion of disadvantaged groups and the scant attention paid to acknowledging and attenuating power differences between participants. On the other hand, transdisciplinary research processes that also integrate the social dimension of sustainability tend to achieve empowerment through the inclusion of disadvantaged communities and through the use of specific tools and methods that seek to recognize and reduce power inequalities. We also found that while cases of 'purely' environmental transdisciplinary research did not report high levels of social learning among participants, environmental-economic and integrated approaches were more successful in achieving this outcome. We offer one possible link between our process features and this outcome: it seems that a high heterogeneity of actors involved in piloting the research processes favors social learning outcomes. However, as mentioned above, this observation should be tested in further research involving a larger sample size, along with the links between a project's embeddedness in longer-term dynamics, its involvement of disadvantaged groups and the attention it pays to power differentials on one hand, and social learning outcomes on the other hand.

Supplementary Materials: The following are available online at https://www.mdpi.com/2071-1050/13/3/1266/s1, Table S1: Coding Scale.

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