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Transdisciplinary research for wicked problems

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Abstract

Addressing "wicked" socio-ecological problems necessitate the integration of knowledge and methods from multiple disciplines. Transdisciplinarity (TD) is one such strategy; its focus is to enhance the comprehensiveness, robustness, and relevance of science via cross-disciplinary team science (CDTS). What separates TD from other forms of CDTS (e.g., multidisciplinary, interdisciplinary) is the meaningful inclusion of a diverse set of nonacademic stakeholders. In collaboration, the TD team draws on tacit and explicit knowledge to co-develop new understandings of vexing "real-world" problems. However, guidance for TD is scant and it leaves open, for instance, questions about how to develop an appropriate team, acquire essential team-based skills, manage the costs of participation, develop individual and group readiness, and satisfy organization expectations, while also attempting to build the trust-based relationships that are fundamental to the approach. Needed are "boundary players" with multi-dimensional skills who transcend the science, facilitate cooperation, and reduce transaction costs.

Keywords Team-based science · Transdisciplinary · Co-development of knowledge · Stakeholders

My name is Michelle Worosz, and I am a Professor of Rural Sociology in the Department of Agricultural Economics and Rural Sociology at Auburn University. I am honored to have been invited to respond to Dr. David Conner's 2022 presidential address to The Agriculture, Food, and Human Values Society. I met David when I was a graduate student at Michigan State University; I will leave the math to the reader! As a long-time member of the Hatch Project, Agriculture of the Middle (NC1198) , I know, and greatly appreciate, his work on values-based supply chains.

Like many rural sociologists, I have a multidisciplinary background. In fact, I took my first sociology class as a Ph.D. student. I have also been a member of many *cross-disciplinary team science* (CDTS) projects. CDTS is a "catch-all" for a range of collaborative endeavors—multi-, inter-, intra-, pluri-, poly-, post-, supra-, and trans-disciplinary (O'Rourke et al. 2019). Over the last few years, I have become more engaged in large-scale projects concerning climate change and resilience. The complexity of this newer work has led me to think more deeply about what CDTS means in the context of collaboration; technoscientific discovery and implementation; and "wicked," socioecological, problems.

The language of CDTS is murky. While deciphering the differences has been referred to as "hair-splitting" (O'Rourke et al. 2019, p. 36), what tends to separate the approaches is the meaning of disciplinary diversity and the degree of social and epistemological integration (O'Rourke et al. 2019). My current work, which centers on "climate-smart" technologies in row crop agriculture, is best described as *transdisciplinary* (TD). TD is a response to the practice of "normal" (Kuhn 1996 [1962]), or Mode 1, science (Gibbons 2013). Mode 1 focuses on the development of explicit knowledge; it is typically the domain of universities, and commonly the way that researchers and government policymakers conceptualize the process of innovation–linear, hierarchical, disciplinary-based, and reductionistic (Gibbons 2013, p. 1289). In the context of normal science, novel innovations are assessed by experts who are internal to the practice of science (Carayannis and Campbell 2013, p. 1293). The results of Mode 1 research are published in specialty journals, often locked behind pay walls, and the innovations are assumed to magically diffuse throughout society.

Transdisciplinary work is Mode 2 science. TD is characterized by the inclusion of co-created knowledge, knowledge that is context- and application-based, and developed

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through meaningful participation of a diverse set of actors and organizations (Carayannis and Campbell, 2013, p. 1293). The goals of TD are to establish collaborative partnerships that construct novel frameworks (Norris et al. 2016) to understand real-world issues, to provide an "orientation and advice for public policies and collective decision making," and to make research and teaching more responsive to societal needs (Arnold 2013, p. 1823; Holzer et al. 2018; Polk 2015; Prell et al. 2021). As such, the quality of TD is assessed by knowledge creators and by innovation users (Carayannis et al. 2013, p. 1294).

What sets TD apart from other forms of CDTS is the incorporation of nonacademic stakeholders, which in my case includes government employees, county extension agents, crop consultants, and farmers. An underlying assumption is that stakeholder expertise, which may be comprised of intuitive know-how and knowledge gained experientially (i.e., tacit), is a valuable resource in co-constructing new knowledge (Arnold 2013, p. 1826; Hegger et al. 2012). As one of my farmer-participants stated, knowledge comes from "*personal experience, you know, being on the farm, and seeing what other people were doing*." [1] Early stakeholder collaboration is critical to the spirit and application of TD; it helps to collectively negotiate the explicit purposes, problems, and questions to be addressed; and to establish a common language that will reduce the transaction costs among technology development, adaptation, and implementation (Gibbons 2013, p. 1290). Thus, in contrast to Conner's (in press) suggestion, that TD is strictly about co-created knowledge, I argue that TD also includes explicit and tacit knowledge.

One may gravitate toward CDTS, particularly transdisciplinarity, for several reasons (Schmidt et al. 2020). Scholars who embrace normative ideals might wish to enhance stakeholder empowerment by fostering participation in the deliberation space (Popa et al. 2015). In practice, this participation may exist along a continuum from consulting stakeholders on decisions to empowering stakeholders to make decisions. Others are concerned about the social-learning space, where the emphasis is placed on increasing trust and adaptive capacity, producing attitudinal and behavior change, or reducing conflict among groups or communities (Popa et al. 2015; Reed et al. 2010). This learning may include both peer-to-peer exchange of information or learning from situational exposure to peers (Priaulx and Weinel 2018). Teams may choose TD on substantive grounds as scientists are rarely able to grasp the breadth and depth of socio-ecological problems without the aid of citizens who have at least some practical and contextual experience necessary to identify and define the problem (Arnold 2013, p. 1825). Thus, the inclusion of stakeholders' voices within the investigative space promises comprehensiveness, robustness, and relevance (Schmidt et al. 2020). A TD approach might also be motivated by implementation goals that are intended to foster transformational change (Hubeau et al. 2018; Popa et al. 2015). Change, it is believed, is more likely to take place when scientists can see the efficacy of their work in situ, and when stakeholders can use and are willing to disseminate, new information about their collaborative efforts (Arnott et al. 2020; Schmidt et al. 2020).

Transdisciplinary science has become increasingly institutionalized; scientific agencies call for the approach to tackle vexing systems problems (e.g., National Academies of Sciences 2019; National Research Council 2014; National Science Foundation 2021). This institutionalization is readily evident in funders' large-scale contributions to collaborative research institutes and centers (Carayannis et al. 2013), as well as the small-scale "request for proposals" (RFPs) that we as students and faculty are most familiar with. The latter includes programs such as the National Science Foundation's (NSF) Research Traineeship (NRT), formally known as the Integrative Graduate Education and Research Traineeship (IGERT), and NSF's newer Growing Convergence program. The language of such programs revolves around inclusivity stating, for instance, that proposals are to incorporate multiple disciplines, a range of underrepresented stakeholders and/or students, and the integration of knowledge that is co-developed. My climate-smart project is funded by the US Department of Agriculture's (USDA) Natural Resources Conservation Service (NRCS). Collaboration was explicit in the RFP; the text states that project teams are to work on-the-ground, and in partnership with, producers including those who are historically underserved, to develop innovative conservation tools and practices (NRCS 2019). Our project aligns with a National Academies of Sciences' (2019) grand challenge–managing soil loss and degradation, improving nutrient use and efficiency, and optimizing water use–by focusing on co-learning about cover crops, variable rate irrigation, soil moisture sensors, and nutrient management. However, moving from project proposal to project implementation is no small feat.

Indeed, transdisciplinarity has been described as aspirational; it is difficult to achieve (Flint et al. 2019, p. 56) and the mechanisms of practice are ill-defined (Brandt et al. 2013, p. 2; Hegger et al. 2012, p. 54), starting with the team itself. Norris et al. (2016) describe the process of developing a TD team as a "wicked problem." This wickedness is entrenched in questions about team composition–what disciplines ought to be represented, who ought to be considered a stakeholder, and when ought new players be added. Generally, academics cooperate as part of their

[1] The direct quotes from research participants come from a study approved by the Auburn University Office of Human Research, IRB# 20–207 EX 2004.

job and to further their professional goals (e.g., building a program, funding students). Faculty will conceptualize the project such that it addresses the criteria laid out in an RFP; and tack on new members when gaps in the science, extension, or teaching emerge; but often fail to appreciate what "integration" entails. Stakeholders are customarily "invited" (Arnott et al. 2020) after the core objectives and approach have been decided. Relinquished is stakeholders' ability to drive the agenda on the front end, which signals that resource-bearing elites, those with skills, knowledge, and authority are still "in charge" (Turnhout et al. 2020).

Teams rarely have explicit knowledge about or are trained in, transdisciplinarity and there is a lacuna of support for the development of relevant skills and expertise (Norris et al. 2016). NRCS, for instance, provides my team with national and state-level technical advisors who oversee the biophysical aspects of our work. However, no guidance is provided for the social components—establishing trust-based relationships, using engagement strategies, or integrating the science. The lack of training and support applies not only to the scientists but also to the practitioners and stakeholders who, in my case, are accustomed to the traditional top-down transfer of technology. In addition to gaps in explicit knowledge of team-based science, project leaders generally lack appropriate tacit knowledge to effectively manage "all the moving pieces" of TD.

Consequently, those who join transdisciplinary teams "pay-to-play," and the costs are not evenly distributed. In my own experience, the cost for farmer-cooperators, those who consent to the use of their land for demonstrations, include the time and expense associated with externally specified and monitored upkeep, along with the stress of knowing that something may go awry—failure of experimental equipment, trials that damage property. For stakeholders who attend our "field days," the cost of admission is the expectation that they will divulge to us, as well as other attendees (e.g., competitors, government regulators), what it is that they do (e.g., trade secrets) and the tacit knowledge that they have gained. Field events provide a critical opportunity for peer networking, but compensation is generally limited to a few lunches from a local BBQ joint and a promise that we will co-create usable knowledge to keep them, at least those with access to capital, moving forward on the treadmill of sustainable intensification. Unclear is whether the continuous development of new strategies for mitigating the agroecological challenges of large-scale monocropping could have a measurable impact when adopted in a patchwork fashion on a small number of acres.

A significant cost of transdisciplinarity is developing "readiness." O'Rourke et al. (2019, p. 29) lay out a typology of attributes that must be satisfied for effective TD. These attributes are intrinsic (e.g., individual, team), extrinsic (e.g., infrastructure, institutional factors), and multi-dimensional–social (e.g., personality, culture), epistemological (e.g., reasoning, disciplinary compatibility), and technological (e.g., ability to adopt new approaches, data sharing and management). Trust, which spans the social dimension of both the individual and team attributes, is fundamental to TD as it ensures psychological safety, confidence in risk-taking, and conflict management (O'Rourke et al. 2019, p. 31). Teams that value inclusivity, diversity, and learning new points of view are inherently more ready to engage the epistemological aspects of TD. Thus, readiness requires attention to members' attitudes and perceptions in the trust-building process. Teams that invest in trust building will be more at ease in giving up sovereignty over knowledge creation; and more prepared to move beyond potential criticisms that stakeholders' partisan and political interests will compromise the credibility and objectivity of their work (Arnold 2013, p. 1825).

Addressing cognitive deficits is a long process (Priaulx and Weinel 2018). Epistemological integration requires time-intensive behaviors such as reading in each other's disciplines or professions; and learning to synthesize and blend each other's concepts and theories, methods and tools, and data and analysis (O'Rourke et al. 2019, p. 32). Developing a common language, however, is most critical to the integration process is as it drives the communication necessary to build trust, openness, and respect (O'Rourke et al. 2019). Differences in the use of language can create significant transaction costs. The costs of incompatible language arise each time my colleagues are unable to understand each other's datasets. As one member stated, "*if I'm going to use your data, I need you to make sure that I know what it means . . . you can't just give me a dataset and then expect me to just miraculously know what treatment one is....*" Lack of agreement about, and follow-through on, data management requires continuous effort to renegotiate how the data are to be obtained (i.e., bargaining), where the data are to be located (i.e., searching), and what the data represent (i.e., monitoring) (Conner, in press). Inconsistencies have led to additional transaction costs in the form of disputes and delays, and it has emphasized our lack of technological readiness (O'Rourke et al. 2016).

Even when ready, transdisciplinary projects can move slowly. As Norris et al. (2016, p. 116) point out, TD projects are iterative; they tend to loop back through various stages to address aspects of the problem, "repair damage induced by a bad decision," or manage extrinsic challenges. TD teams are invariably situated within organizations laden with cultural norms, administrative policies and practices, and infrastructure issues (O'Rourke et al. 2019, p. 29) that can impact progress toward TD (Arnold 2013). These external conditions create additional strain on faculty and practitioners who must satisfy a growing list of professional metrics–having a continuous stream of high-impact publications, multiple high-dollar grants, and a small army of graduate students. Junior faculty are particularly susceptible when a project veers off course as they have little "wiggle room" during the tenure and promotion process. Turnover (e.g., students who graduate, stakeholders who leave) creates another overhead problem. Attrition breaks project momentum, deprives the team of critical expertise (Norris et al. 2016, p. 118), and fractures stakeholder relationships that cannot be simply fixed with new people. As a result, TD can take on a seemingly glacial pace, which in turn, can chip away at trust.

Time constraints coupled with institutional incentives can have a negative influence on participants' commitment to transdisciplinarity (Cooke 2018, p. 63). My team has shown remarkable growth, but collectively we fight inertia; to consistently engage producers and stakeholders in both frequent (Reed et al. 2014) and novel ways that will enhance their voice, their sense of project ownership, and their feelings of empowerment. Conner (in press) calls attention to the importance of "glue players," those who are intelligent and humble, flexible and patient, and trustworthy and dedicated. These are the players who keep a project moving. But, while Conner focuses on the hard work of glue players, I argue for a somewhat different player, the "boundary spanner." Boundary spanners, or boundary players, are transformative, but not because they *do* the research. Rather, the work of boundary players transcends the research; they have a strong multi-dimensional skill set including the ability to identify and interpret a body of language, see other perspectives, and provide authentic leadership (Delozier et al. 2022). Boundary players can communicate in ways that facilitate meaningful, research-relevant, cooperation that is needed to engage citizens and maintain partnerships (O'Rourke et al. 2016, p. 25). They reinforce collaboration which otherwise wanes without continuous "care and feeding," by focusing on motivation, coordination, and interaction. Boundary players also address power differentials (Collien 2021); they provide a neutral zone where "values can be explored, assumptions can surface, and internal hierarchies (can be) removed" (Delozier et al. 2022). Without strong boundary players, a team can ostensibly do everything "right," but it will not be enough to reach transdisciplinarity.

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Declarations

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