Structure Matters: Real-World Laboratories as a New Type of Large-Scale Research Infrastructure

A Framework Inspired by Giddens' Structuration Theory

Uwe Schneidewind, Karoline Augenstein, Franziska Stelzer, Matthias Wanner

In order to grasp the transformative potential of real-world laboratories, it is essential to understand them as a large-scale research infrastructure. Unlike single transdisciplinary projects and processes, real-world labs are not only about temporary interventions or knowledge integration. They are also about establishing long-lasting spaces for transformation and reflexive learning.

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Real-World Laboratories and Transdisciplinary Transformative Research

In recent years, the concept of the real-world laboratory (RwL) has received considerable attention, both scientifically and politically (MWK 2013, Wanner et al. forthcoming, Schäpke et al. 2017). Early notions of RwLs and real-world experimentation rather focused on a sociological reflection of society as "increasingly developing into an experiment on itself on its ways of coping with the insecurity and uncertainty of the modern world" (Gross and Krohn 2005, p. 79). In the current, proactive notion, RwLs are usually being understood as a targetedly set up of a research "infrastructure" (Jahn and Keil 2016) or a "space" (WBGU 2016, p. 512) in which scientific actors and actors from civil society cooperate in the joint production of knowledge in order to support a more sustainable development of society. A RwL is then understood as a place in time in which specific actors mutually invent and conduct real-world experiments (Gross et al. 2005) in order to gain systems knowledge, target knowledge, and transformation knowledge (WBGU 2016, p. 512).

Although such a laboratory establishes a *structure,* most discussions about RwLs focus on *processes* of co-design, co-production, and co-evaluation of knowledge (see figure 1, p. 14). Surprisingly, the structural dimension receives little attention in this growing field of literature. Building on Giddens' theory of structuration, this article therefore develops a framework for conceptualizing the structural dimension of RwLs and elaborates it focusing on their spatial and thematic scope.

Since RwLs are a transdisciplinary concept, we start with a link to Scholz (2017) who proposed three "schools" of transdisciplinary transformation research:

1. transdisciplinarity (Scholz et al. 2006, Jahn et al. 2012, Lang et al. 2012),
2. transition management (Rotmans et al. 2001, Loorbach 2010, Loorbach and Rotmans 2010), and
3. transformative science (Schneidewind and Singer-Brodowski 2014, WBGU 2011).

In these schools, RwLs are looked at in different ways: Jahn and Keil (2016, p. 248) consider them as one element in the process of transdisciplinary research. In transition management, they are typically structures that nurture niche development, that is, experimental spaces for innovation and learning (Frantzeskaki and Kabisch 2016, Nevens et al. 2013, Wittmayer et al. 2014). Recent developments in this strand of research have developed approaches for reflecting actor roles in transition research (Wittmayer and Schäpke 2014, Wittmayer 2016). Transformative science explicitly takes reflexivity as a starting point and considers RwLs as reflexive learning spaces, which combine practice and scientific per-

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spectives (WBGU 2016, p. 512, Wanner et al. forthcoming, Schäpke et al. 2017, Schneidewind and Singer-Brodowski 2015).

As a consequence, the degree to which the structural level of RwLs is taken into account differs markedly across the three approaches: Jahn and Keil (2016, p. 248) classify them only as a process element within the transdisciplinary research process. In transition management, they are considered as an element of different forms of niche experimentation and embedded in structuration processes at work between niche, regime and landscape levels. Transformative science goes a step further and combines a view on the more abstract notion of structure (i. e., transformation as structuration) with the concept of RwLs as a physical research "infrastructure" (Schneidewind and Singer-Brodowski 2014, p. 134).

Structure as the Blind Spot of the Real-World Lab Debate

We want to raise awareness for the importance of the structural dimension of RwLs. Scientific and non-scientific actors refer to structures (including physical infrastructure as well as interpretative schemes or social norms) when jointly involved in knowledge production processes. The RwL represents these different types of structure. Building on Giddens' structuration theory, we show that analyzing RwLs on a structural level addresses blind spots in the debate and offers a valuable addition to the literature on transdisciplinary processes. Finally, we develop a typology of RwLs focusing on the "infrastructural" scale and scope as well as the more abstract structural features – and the interlinkages in analyzing abstract and concrete (infra-)structures.

Referring to Giddens connects well with the field of transition research, where structuration theory has been a building block of understanding dynamics of change in the multi-level perspective (Geels and Schot 2007, Schot and Geels 2008). Recently, a number of researchers have (re-)focused attention on the role of structure, interrelations between actors and institutions and the role of power in transformations understood as processes of structuration (Avelino and Rotmans 2011, Fuenfschilling and Truffer 2014, 2016, Wittmayer et al. 2016), in order to gain a more in-depth understanding of how structuration processes play out across niche and regime levels. The RwL can be understood as a structure for nurturing niche development, or a space for experimentation that interacts (and aims at changing) structural conditions at the regime level. Thus, a more in-depth focus on structure as a basic concept is useful. Apart from this theoretical perspective, we want to add a concrete "infrastructural" perspective as well as a reflexive note on the role of science and researchers: Giddens' term of structure helps to emphasize that scientific activity is always based on rules (e. g., rules of proper research and use of methods in different disciplines) and resources (e. g., funding, laboratories, libraries). The two key challenges of RwL are that 1. both scientists and civil society actors are involved in the process of knowledge production and 2. that it takes place in real-world environments instead of scientific laboratories. Different rules and extended forms of resources apply to these enlarged contexts (see below).

Giddens' Structuration Theory as a Conceptual Framework[1]

Giddens defines structure as "rules and resources, recursively implicated in the reproduction of social systems" (Giddens 1984, p. 377). Structures are "rule-resource sets" which are included in the institutional framework of social systems and have a virtual existence, that means they do not exist in isolation or independent of actors. Rather, they are (re)produced through agency, where actors draw on rules and resources in social interaction. Rules influence actors' practical knowledge, resources define actors' capacity to act. Giddens divides rules as well as resources into two subcategories. He distinguishes *rules of the constitution of meaning* (signification) which result from reference to interpretative schemes and *rules of normative sanction* (legitimation) which are justified by reference to norms. Giddens differentiates resources in *allocative* and *authoritative resources*. Actors can exercise power by drawing on rules and resources.

Giddens conceptualizes actors as human beings equipped with reflexivity and intentionality. Motivation, rationalization, and reflexive control are essential for agency. Reflexive control of acting means actors are controlling their activities as well as social and physical aspects of their context. Actors communicate with each other by referring to shared interpretative schemes and in doing so reproduce structures of signification. They gain power (or facility) over other actors by drawing on allocative and authoritative resources and in doing so they reproduce structures of domination. Finally, they evaluate and sanction other actors' behavior by making use of norms, thus reproducing structures of legitimation. >

From a structuralist perspective, a real-world lab is a research infrastructure in which interpretative schemes and norms as well as allocative and authoritative resources are mobilized for real-world experiments.

1 The following reconstruction of Giddens' theory of structuration is based on Schneidewind (1998, pp. 137 ff.).

Giddens' idea of the "duality of structure" captures the interlinkage and mutual conditionality of structure and agency. "Structures are medium and result of acting" (Ortmann et al. 2000, p. 1). Structuring is creating and creation at the same time. This reflexive character creates the duality of structure (Giddens 1984, p. 374). Giddens' most significant achievement is the combination of the microanalysis of actors and their intentions on the one hand and the macroanalysis of objective structures on the other (Smith 1983).

The Structural Dimension of Real-World Labs

Transdisciplinary processes can be understood as a specific form of joint action of scientists and practice actors which serves the collective production of knowledge. The aim is to achieve a better understanding of (scientific sphere) as well as to activate such transformation processes (practice sphere). Giddens' understanding of structure highlights the meaning of reflexivity of acting in RwLs, and the specific form the duality of structure takes in these laboratories: scientists refer to rules and resources, that is, the modalities of structuration. At the same time, they try to change them in line with a sustainability-oriented transformation during their interaction with practice partners.

Here we can distinguish the structural level of the RwL and the process level of transdisciplinary research (see figure 1). Actors in a transdisciplinary process rely on the structural elements of the RwL to establish "agency" in terms of an intentional and conscious management of knowledge production and intervention processes. A structural perspective thus complements the process-oriented view on RwLs (see Rogga et al. 2018, in this issue). From a structuralist perspective, a RwL is a research infrastructure in which interpretative schemes and norms as well as allocative and authoritative resources are mobilized for real-world experiments. Simultaneously, these experiments enable reflexivity, re-interpretation and – by influencing the involved structural dimensions – sustainability-oriented structural change.

Modalities of Structuration in Real-World Labs

Based on our own experience with real-word laboratories, we find that the transdisciplinary research process benefits from a better understanding of the specific modalities of structure actors draw upon in the context of RwLs (see table 1).

Interpretative schemes are crucial for RwLs because cooperation needs to be built on the basis of a common understanding of key concepts and terms. This applies to the RwL itself. Using this term in a concrete real-world setting is often problematic because of different understandings. Also, to achieve science-practice cooperation at eye level is only possible if civil society stakeholders are involved on an equal footing rather than as "test objects" in a laboratory. Mobilization and commitment of actors requires a minimum of local identity, for example, with regard to the quarter, city, or region in which the RwL is embedded. This is why a clear distinction and description of RwLs and their link to locally set definitions and identities are of great importance.

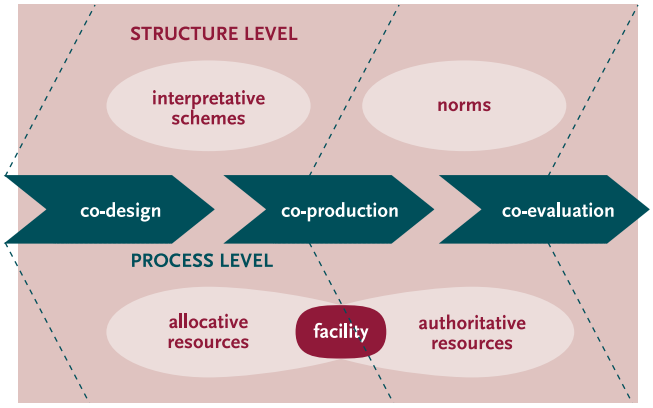

FIGURE 1: Structural perspective of, and process-oriented view on real-world laboratories.

In many RwLs, the level of ***legitimatory rules*** is sensitive. Are scientific actors and practice actors able to refer to shared norms which justify their interference in concrete quarters or city settings? The justification of such a science-driven intrusion into society depends on many factors: regional differences in the affinity towards science, the recognition and reputation of the local scientific institutions, and the credibility of the scientists involved. Our experience is that establishing and stabilizing such legitimation structures is becoming more important as soon as RwLs start engaging with and changing existing structures of power.

The availability of ***allocative resources*** has an immediate effect on RwLs. The scope of an intervention depends on human and financial resources. These define the depth of the initiated transformation processes: how many people can be reached by RwLs? Is it possible to utilize whole areas, buildings, infrastructures, quarters for real-world experiments? Are investment resources available for testing, for example, new forms of regenerative energy supply?

Apart from that, the scope of RwLs depends on ***authoritative resources,*** that means, the possibility of utilizing power in political or organizational governance processes: is it, for example, possible to experiment with road closures to bring forward mobility experiments? Can official communication channels promote real-world experiments? Can a management board motivate members or employees to participate in real-world experiments?

The specific character or "Eigenart"[2] of each RwL is determined by the specific interplay of its structural elements. The structural

2 Using the concept of "Eigenart" as introduced by the German Advisory Council on Global Change (WBGU 2016).

TABLE 1: Modalities of structuration (based on Giddens 1984) in real-world laboratories.

MODALITIES OF STRUCTURATION			
INTERPRETATIVE SCHEMES	NORMS	ALLOCATIVE RESOURCES	AUTHORITATIVE RESOURCES
■ shared notions/terms ■ shared narratives ■ local identity	■ rules of legitimized interventions ■ credibility of actors ■ established reputation of actors	■ investment resources ■ civil society commitment (working hours, expertise)	■ political power ■ management power

specifics of RwLs have a significant impact on the type of transdisciplinary processes taking place within the RwL. A clear analytical understanding of the different structural dimensions facilitates the identification of different "patterns" emerging in RwLs – with patterns offering a basic understanding of how experiences made in one particular RwL can be learned from and transferred to other contexts.

Spatial and Thematic Scope of Real-World Labs as Application of the Structural Dimensions

In order to arrive at an understanding of the particular "Eigenart" of each RwL, an analysis of its specific structural features needs to be embedded in an understanding of how the RwL is positioned in time and space, that means, what its particular context and tangible form is. Focusing on structural dimensions as applied in the framework proposed here, the thematic scope of a RwL is linked to "interpretative schemes" and "norms" actors draw upon. The spatial scope – which may range from a housing block to a neighborhood or an entire city – defines the type of allocative and authoritative resources relevant for a specific context. Similar to recent advances in the "geography of transitions" (Coenen et al. 2012, Hansen and Coenen 2015, Truffer et al. 2015) as well as a re-emphasis of the local dimension in global sustainability research (Müller-Mahn 2005, 2012), it is emphasized here as well that attention has to be paid to scale and scope. It is crucial to understand how structural features as discussed above are interlinked with the scope of RwLs, which can be differentiated into 1. spatial, 2. thematic, and 3. temporal scope.

Analyzing literature, one finds that a broad range of real-world, experimental research settings are referred to as RwLs: spatially, the term covers many forms from living labs in individual households to an entire city as an urban laboratory. Looking at content and research questions, we can distinguish between mono-thematic (e.g., about specific forms of sustainable mobility) and multi-thematic RwLs, which deal with a city quarter's transformation including all kinds of aspects of sustainability (Hilger et al. submitted).[3] In all of these settings, co-production of knowledge takes place which can be described by the existing process schemes developed in the field of transdisciplinary research (Jahn et al. 2012). However, for example, the differences between a household-related living lab for influencing heating habits and an integrated sustainable transformation strategy of an entire city quarter can only be discovered when looking at structural dimensions. Depending on the spatial and thematic scope of a RwL, very different (allocative and authorative) resources and rules (interpretative schemes and norms) are involved. At the household level, specific family codes are important legitimation structures, whereas at the level of city quarters, larger discourse patterns and historical traditions need to be considered, for example, for the inclusion of civil society in urban governance processes. Similarly, the need for financial and other resources can be relatively low or very high, for example, related to renewable energy infrastructure or urban farming systems. Our experience shows that spatial and thematic scope are suitable dimensions for systemizing situations in RwLs with reference to the different structural dimensions (Schneidewind 2014).

The character of each real-world lab is determined by the specific interplay of its structural elements. The structural specifics have a significant impact on the type of transdisciplinary processes taking place within the lab.

Temporal Scope

The temporal scope is the third dimension: structural reflections are becoming even more crucial when RwLs are being operated for many years and decades. This cannot simply be understood as a sequence of process episodes, but always has to reflect the structural changes emerging over time. This is crucial from a sustainability transitions perspective: profound change processes only take place as structural adjustments over long-term periods. Hence, >

3 We provide a compilation of real-world laboratories with different spatial and thematic scopes (examples from Baden-Württemberg, North Rhine-Westphalia, and Switzerland) as a supplement: *www.oekom.de/supplementary-files.html#c11350*.

BOX 1: The Real-World Laboratory *Wuppertal* and Its Structural Dimensions

Since 2013 the Wuppertal Institute for Climate, Environment and Energy together with the University of Wuppertal have started to form a real-world laboratory designed according to the principles of the German Advisory Council on Global Change (WBGU) (see Hilger et al. submitted). The experience gained in Wuppertal is suitable for illustrating the relevance of the different structural dimensions of real-world laboratories with a wide spatial and thematic outreach.

At the structural level of *interpretative schemes (signification)*, it was possible to establish the term "real-world laboratory" as a positive and fruitful concept for the joint work of Wuppertal actors with the scientific actors. There are common understandings about urban key districts and their actors for transformation processes in Wuppertal. Thereby, common narratives have emerged in the last years that structure the transformation processes between scientific and practical actors. Currently the establishment of an enhanced understanding of prosperity, including measuring metrics for the city of Wuppertal is under way. This will create important interpretative schemes and norms for the transformation processes in the city.

Considering the rules of normative sanction (legitimation), based on the existing high acceptance and positive assessment of the Wuppertal Institute for Climate, Environment and Energy and the University of Wuppertal in the local community, the role and the ideal of the scientific staff to act as transformative actors has been met by strong support in the urban society (e. g., reflected in a correspondingly positive [local] media reporting).

Allocative resources are also crucial in Wuppertal because of the substantial transformative outreach. Over the past five years, several research projects at the German Federal Ministry of Education and Research (BMBF) and the EU level could be raised to support the transformation processes in Wuppertal, thereby mobilizing personnel and material resources for transformation processes in the areas of energy, mobility, housing, civic engagement, citizen science, food, and sharing processes. In plus, one of the first urban individual well-being panels for a city is currently set up in Wuppertal with active support of local companies like the local savings bank and the public utility company[a].

With regard to authoritative resources, direct access to key representatives of the city and regional politicians as well as the state government are of great importance. Cooperative collaboration with key political actors across different political camps allows the testing of new transformative designs.

a *www.gluecklich-in-wuppertal.de*

a series of isolated, short-termed laboratory processes can neither realize the factual transformations nor provide the data necessary for research on long-term transformations. Apart from these short-term experiments with a focus on pattern learning, it is thus important to also establish RwLs as research infrastructures of greater spatial, temporal and thematic reach because certain processes of change, that is, the transition toward sustainability, can only be established in the long term. This insight has been taken up by the German Advisory Council on Global Change (WBGU), which has called for establishing "50 urban real-world laboratories for 50 years" (WBGU 2016).

Summary

In this paper we highlighted the importance of structural dimensions of RwLs. Giddens' structuration theory provides a promising framework to better understand the interlinked abstract and physical (infra-)structural features of RwLs. We argue that research on and in RwLs needs to be sensitive to the spatial, temporal, and thematic scope of structuration processes. A systematic conceptualization of these dimensions remains an important task for future research. In order to arrive at such a more in-depth understanding and possibly an improvement in the transferability of knowledge created in RwLs, the idea proposed by the WBGU should be taken up: building RwLs for the long term and focusing more explicitly on their structural dimensions. First steps have been taken in the German city of Wuppertal where a RwL infrastructure has been built up over the course of various projects (see box 1) including a broad variety of resources, actors, and topics in the broader search and learning process for sustainable transitioning (Augenstein et al. 2016, Rose et al. 2017, Hilger et al. submitted, Wanner et al. forthcoming).

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