Learning in Real-World Laboratories

A Systematic Impulse for Discussion

Real-world laboratories (RwLs) are a form of transdisciplinary research that facilitates learning processes as part of its transformative objectives. Nevertheless, little conceptual effort has been put into the understanding, planning, and evaluation of the learning dimension of RwL work. This paper applies a systematic approach from the discourse on education for sustainable development (ESD) to differentiate three perspectives on the various learning processes occurring in RwLs and exemplifies them with experiences from the RwL Urban Transition Lab 131 *in Karlsruhe.*

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As an approach for transformative research, real-world laboratories (RwLs) have gained growing attention in the past few years. RwLs are part of an experiential turn in social science in general (Overdevest et al. 2010) and a solution-oriented research agenda in sustainability science (Miller et al. 2014, Wiek and Lang 2016). They have been conceptualized as "places of learning" (Parodi et al. 2016 b, p. 10, own translation; Beecroft and Parodi 2016 a, p. 7) or "societal context (...) to learn about social processes" (Schneidewind 2014, p. 3, own translation). Schäpke et al. (2018, in this issue) even see learning as a core characteristic of RwLs, since it fosters the individual and collective capacity to deal with challenges and differences and thereby supports the transformative objectives of RwLs. However, little is known about their potential to facilitate learning. As more and more RwLs are being set up (Beecroft and Parodi 2016 b), questions arise regarding, for example, the potential of RwLs for social learning and education for sustainable development (ESD) (e. g., Schneidewind and Singer-Brodowski 2015).

To start a systematic discussion, we address RwLs from a combined didactical and methodological perspective (Beecroft and Dusseldorp 2012), conceptualizing them as "learning environments". We apply a conceptual framework that describes the contribution of educational science for sustainability science in general, differentiating three theoretical perspectives (Barth and Michelsen 2013). The distinction between individual competencies, social learning, and inter- and transdisciplinary cooperation serves as an analytical tool for the first goal, to map out the potential RwLs carry for facilitating learning. The second goal is to include "learning" as a dimension to the methodological and self-reflexive discourse on RwL research, following the same framework.

After outlining our understanding of an RwL, we will present the analytical framework and apply it to RwLs. Early experiences from one RwL in Karlsruhe will serve to illustrate the analysis. We will conclude with a systematic overview on the mutual benefits between learning, transformation and research in RwLs.

Real-World Laboratories

To achieve transformation, various societal actors have to learn new perspectives, skills, competencies, practices and develop new concepts of their own role. Transformative research (see Schäpke et al. 2016), such as RwL research, should embrace this necessity to enable learning processes and reflexivity as a key dimension of their methodology.

In the flagship report of the German Advisory Council on Global Change, RwLs are defined as "scientifically designed spaces of collaborative sustainability research involving intervention" (WBGU 2016, p. 512). Further definitions of RwLs (Parodi et al. 2016 b, Beecroft and Parodi 2016 b) have been developed in a broader theoretical-conceptual discussion between RwL practitioners, including a university course on RwL research. They highlight

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BOX 1: *Urban Transition Lab 131 (R131)*

The Karlsruhe Institute of Technology (KIT) established the *R131*, which aims to achieve a dense sustainable development of the district Karlsruhe Oststadt in a transdisciplinary process. The objectives are transformation, research, and educational aspects. Scientific aims are the generation and testing of knowledge required for a sustainable transformation of existing cities. The lab runs eight real-world experiments (RwE), four mainly driven by scientists (energy concept, mobility, social issues and urban space, sustainable consumption) and four mainly driven by citizens *(Your SustainabilityExperiment)*. The lab also offers transdisciplinary project courses (see below). The RwEs are accompanied by a sustainability assessment. The lab serves as a learning environment, networking platform and infrastructure, enabling sustainability experiments arising from the district's needs and interests.

seven key characteristics: 1. research orientation, 2. normativity, 3. transdisciplinarity, 4. transformative approach, 5. inclusion of civil society, 6. long-term orientation, and 7. lab character both in terms of local contextualization and experimental strategy. These characteristics distinguish an RwL from similar approaches (see also Parodi et al. 2016a, Schäpke et al. 2017). They can be found in several operating RwLs (e.g., the *BaWü Labs,* see Parodi et al. 2018, in this issue) and are used here to explore the relation between an RwL and learning in a structured way.

Three Educational Perspectives on Real-World Laboratory Research

The definition of RwLs locates them at the core of sustainability science. Especially in this discourse, pleas have been made to relate the sustainability research more closely to educational approaches such as higher education for sustainable development (e.g., Mochizuki and Yarime 2016). One of the most elaborate approaches comes from Barth and Michelsen (2013, updated in Barth 2015). They have analyzed how the idea of sustainability influences practices of education on the one hand, and how educational science can contribute to sustainability on the other hand. Based on an extensive literature review, they argue that the high potential of educational perspectives to sustainability science is still mostly unused. They differentiate three educational perspectives: individual competencies for sustainability, organizational change and social learning[1], and inter- and transdisciplinary collaboration. The perspectives are all based on an understanding of "learning" as an active, self-directed and situated process of socially-embedded meaning making with the aim of greater participation (Lave and Wenger 1991) and higher reflexivity (Mezirow 2000).

RwLs are typically designed as a space that supports interventions, rather than as an intervention in itself. They offer a supportive surrounding for cooperation, mutual understanding, addressing goal conflicts and re-adjusting the spatial dimension of experiments and interventions. This design as a supportive space can best be addressed as a "learning environment" in educational terms, even if it has not been designed as such. Among a multitude of definitions and conceptual suggestions for "learning environments" (Jonasson and Land 2012), Land et al. (2012, p. 8) identify four core characteristics of learning environments: "(a) centrality of the learner in defining meaning; (b) scaffolded participation in authentic tasks and sociocultural practices; (c) importance of prior and everyday experiences in meaning making; and (d) access to multiple perspectives, resources, and representations". The conceptualization of an RwL as a learning environment highlights the potential of individual and collective meaning making through mutual cooperation between practitioners and scientists in an ongoing process of negotiating different perspectives.

This notion of learning environments corresponds closely to the core idea of transformative research in RwLs. The experience from interventions (e.g., in field experiments, real-world experiments, workshops, etc.) and the characteristics of RwLs in general can inspire new approaches and developments in the discourse on learning. How RwLs can profit from the perspectives from educational science will be discussed below, including examples from the RwL *Urban Transition Lab 131 (R131)*[2] (box 1).

Individual Competencies for Sustainability

The first contribution of educational science addresses individual learning and more specifically the individual competencies for engaging in sustainability transformations. The overall debate about competencies for sustainability transitions has identified anticipatory, normative, system thinking, strategic, and interpersonal competencies as decisive (Wiek et al. 2011). A learning environment addressing real-world sustainability problems can support learners to develop these competencies. An RwL offers such an authentic context. Here, learners can become part of solution processes, in the areas of both research and practice (Wiek et al. 2014). They can apply theoretical knowledge to a specific problem and generate new knowledge by translating experiences into more abstract concepts (Schneidewind and Singer-Brodowski 2015, p. 12). This two-sided process can be described as an experiential learning cycle (Kolb 1984), with the interplay of knowledge exchange, action, and reflection at its core. Such a learning cycle corresponds closely to the experimental and reflexive approach of RwL research.

Following such a perspective, an RwL running transdisciplinary (3) and transformative (4) processes serves as a learning environment for individual competency development. It is particularly the experimental approach which can lead to competency development of the individual learner embedded in an evolving social community (Wiek and Kay 2015). From an educational perspective, one can derive the necessity to address the individual competency development actively. In RwL research, we suggest

1 In this paper, we focus on social learning.
2 German: *Reallabor 131: KIT findet Stadt*, *www.itas.kit.edu/projekte_paro15_qzrealab.php*, *www.quartierzukunft.de*, see Waitz et al. (forthcoming). The evaluation is a result from the internal cooperation of *R131* with the Karlsruhe School of Sustainability to identify synergies and future collaboration potential.

to jointly explicate learning goals in advance. This is advisable not just for students in university courses, but also for practice partners and scientists involved, ensuring individual competency development for all groups. Based on the elaboration of these learning goals, planning knowledge exchange, action and reflection can incorporate didactical aspects, that is, through time-slots for personal and theoretical reflection or communication techniques to enhance mutual understanding. The achievement of the learning goals should also be included into the evaluation process, at least ex post. Both the long-term orientation (6) and the lab character (7) of RwLs can be used to facilitate learning beyond singular interventions and experiments and adapt the RwLs experimental and interventional methodology accordingly.

R131 in Karlsruhe uses transdisciplinary project courses to facilitate learning, practical, and scientific outcomes in one integrated format. In these courses, students are being encouraged to explicate their individual learning goals in advance, and reflect upon the outcomes of their projects in terms of practical results, theoretical findings, and individual learning. This "goal triangle" was used both as a basis for decisions in the project work and for identifying necessary support from the teaching staff. At the end of the project course, these expectations are being used to assess the outcomes of the course from a participant's perspective: in learning portfolios, students reflect upon their own diverse learning outcomes. These portfolios usually entail the participants' level of personal competencies, their knowledge on the exemplary subject, surprises, and often link to their experience in local civil society organisations (CSOs). Sometimes, the expectations for mutual learning with other stakeholders become clear only ex post.

Social Learning

The second contribution of educational science is to identify, describe and understand the various informal processes of joint or mutual learning between actors from diverse backgrounds in terms of "social learning" (Barth 2015, p. 163 ff., Pahl-Wostl and Hare 2004, Keen et al. 2005). This theoretical perspective frames processes of heterogeneous stakeholders – individuals or groups – interlacing their perspectives and coping with conflicting aims as learning together (Pahl-Wostl et al. 2007). Although the actors also develop individual competencies in these processes, the social learning perspective focuses on assumptions and values underlying groups or a whole social system. The underlying assumptions can be described as meaning perspectives in terms of orienting cognitive and perceptual frames, which aim at structuring perceptions and experience (Mezirow 2000). Social learning is "an intentional process of collective self-reflection through interaction and dialogue" (Fernandez-Gimenez et al. 2008). Through building a common learning environment, RwLs can offer an ideal space for analyzing and negotiating divergent meaning perspectives, thereby going beyond given assumptions and in the end leading to higher reflexivity.

The experimental mode (7) of work in RwLs allows for mistakes, iterations, and changes. RwLs thus support a livid learning culture and enable reflexivity. In most cases, scientists initiate and run RwLs, emphasizing their research potential. Nevertheless, they can also create joint learning occasions for people from different backgrounds and sharpen their perspectives on further elements of social learning: the identification of the participants with sustainability solutions through a process of collective meaning making. RwLs facilitate the participation of various stakeholders because of their strong civil society orientation (5), and have the potential to nurture ownership of the sustainability issue at hand. They can include not only established organizations but also informal and loosely coupled networks working on the solution of a singular sustainability problem. Especially this organizing principle of RwLs – and their internal structures, such as experiments, groups, etc. – can play a crucial role in framing RwLs as a learning environment for adults. It is an informal setting focused on one sustainability problem and open for engaging various non-university actors in RwLs across all age groups. The explication of normativity (2) – ideally as an elaborate concept of sustainable development – can play an important role to stimulate these negotiations and learning processes in RwLs.

The educational perspective of social learning can inspire RwLs to take a step back and look at the many-faceted processes of communication, negotiation, and learning that take place in the lab, to assess, support, evaluate, and sustain them. Educational science has inspired a broad range of methods to facilitate and enable such social learning processes (i. e., moderation, reflexive elements, non-violent communication, theatre of the oppressed, socratic discourse).

In *R131,* the competition format *Your Sustainability Experiment* (Meyer-Soylu et al. 2016, Trenks et al. forthcoming) has been developed, in which small groups of stakeholders carry out self-experiments, receive organizational support, regarding, for example, visibility, networking, internal working processes, and minimal funding. Their projects are closely monitored by an accompanying research team, serving both as facilitators and as scientific counterpart: individual and social learning complement each other. The close cooperation makes the process accessible for evaluation, even though the project design was not systematically based on educational theory. A first analysis shows that the engaged citizens do not necessarily differentiate between their learning outcomes and practical outcomes, they see them as closely linked.

Inter- and Transdisciplinary Collaboration

The third contribution of educational science – conceptualizing the modes of inter- and transdisciplinary collaboration – describes the cooperation both between disciplines and between science and other stakeholders as a "community of practice" (Lave and Wenger 1991). Learning is understood as a contextual and situated practice rather than as a purely cognitive process. Developing expertise through learning does not only encompass understanding the respective community of practice (or forming a new one), but also the transformation of one's own role and language.

RwLs are spaces that establish communities of practice to facilitate intense interactions between researchers and practitioners, in line with their abovementioned research orientation (1),

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TABLE 1: Mutual benefits between learning, transformation, and research in real-world laboratories, based on a systematic from Barth and Michelsen (2013).

	HOW CAN RWLS FACILITATE LEARNING?	HOW CAN RWLS PROFIT FROM INCLUDING LEARNING SYSTEMATICALLY?
individual competency development	■ create an inspiring learning environment for scientists, students and practitioners alike ■ make the interventions experimental and support reflexive learning cycles ■ identify individual learning goals in advance	■ clarify goals in RwL activities also in terms of learning, e. g., based on a competency model from ESD ■ consider using classical didactical approaches (problem-based learning) ■ include learning outcomes in the evaluation and analysis
social learning	■ structure and facilitate the discourse between stakeholders with different perspectives and complementary knowledge ■ empower civil society partners systematically and strengthen ownership ■ offer a protected space to build trust between stakeholders and mediate in conflicts	■ reflect communication and negotiation processes in RwL also as social learning processes ■ make normativity of sustainability issues explicit and use it as learning stimuli ■ use learning opportunities as an incentive for various stakeholders
inter- and transdisciplinary collaboration	■ facilitating inter- and transdisciplinary collaboration requires (mutual) learning ■ use the RwL to compare collaboration experience between different projects ■ train new partners for transdisciplinary cooperation and offer opportunities for reflection to all	■ create a heterogeneous community of practice based on trust ■ develop a methodology that includes learning as one dimension of transformation ■ take experiences of epistemic difference serious, they can carry valuable insights, and they can rip a project team apart ■ make the RwL a learning process in its own right

transdisciplinarity (3), and shared aim for transformation (4). Independent communities face the task of familiarizing themselves with each other's practice to facilitate mutual learning and, subsequently, the integration of different forms of knowledge. By confronting, interrelating, and integrating different epistemic cultures (Knorr Cetina 1999)[3], RwL research can lead to an experience of epistemic difference[4]. It can, however, also help to re-integrate epistemic cultures bound to different roles, for example, as a neighbour, a scientist and a member of a CSO. The special mode of experimenting and intervening in real-world processes bears additional challenges. These encompass the danger of frustrating involved actors, for example, through too academic approaches, integrating the findings of different experiments on a very abstract level, and the challenge of letting go in processes of empowerment.

From a perspective based on educational sciences, a key aim is to prevent the stabilization of mutual stereotypes through the experience of epistemic difference. Reminding actors of their multiple roles and offering a protected space to establish mutual trust and give room for self-reflection which can – at times – be very challenging, are typical strategies to cope with these issues.

In the *R131* experiment *Sustainable Energy Concept for Karlsruhe Oststadt,* electrical engineers, who never worked in an inter- or transdisciplinary manner before, were involved in highly unfamiliar processes over 18 months: co-designing the experiment with citizens, cooperating with scholars from social sciences and humanities, and carrying out citizen workshops. In doing so, various processes of mutual learning have taken place and the experiences have deeply affected their own role, language(s) and self-conceptions. However, not all engineers interested to take part in the experiment in the first place felt comfortable with the experiences of epistemic and cultural difference. Several of them did not want to give up their role as distanced scientists. In consequence, the *R131* team plans to include training events already for potential participants, preparing them for the experience of epistemic difference and their changing or overlapping roles in the transdisciplinary process.

3 The term "epistemic cultures" refers to those sets of practices, arrangements, and mechanisms "bonded through affinity, necessity, and historical coincidence – which, in a given field, make up *how we know what we know.* Epistemic cultures are cultures that create and warrant knowledge" (Knorr-Cetina 1999, p. 1).

4 This can represent a situation when a person is confronted with different epistemic cultures (i. e., of disciplinary scientific communities, which may be inconsistent or contradictory to the epistemic cultures of the own discipline or the perspectives of practitioners) and starts to reflect upon them.

Real-World Laboratories Facilitate and Profit from Multi-Facetted Learning Processes

From an educational perspective, we have conceptualized RwLs as learning environments that facilitate learning on three interconnected levels, personal competency development, social learning, and inter- and transdisciplinary collaboration. This perspective can describe existing and inspire new methodological strategies for RwLs, both to enable learning within RwLs and to advance RwL research as it shows close links to the seven core characteristics of RwLs. Table 1 gives a brief overview of the mutual benefits with exemplary contributions.

This brief systematic impulse for discussion shows that RwLs offer a potential for learning and that they can, in turn, profit from a differentiated educational perspective for their methodological development, by systematically including learning as a characteristic of their design. Further research on the inclusion of educational concepts and methods in RwLs is required, for example, relating to the feasibility of learning aims as part of (formative) evaluation processes, the competencies required for RwL research, and the continuous transformation of an RwL as a learning process in its own right.

References

Barth, M. 2015. *Implementing sustainability in higher education: Learning in an age of transformation.* London: Routledge.

Barth, M., G. Michelsen. 2013. Learning for change. *Sustainability Science* 8/1: 103–119.

Beecroft, R., M. Dusseldorp. 2012. Technikfolgen abschätzen lehren – Bildungspotenziale transdisziplinärer Methoden. Zur Einführung. In: *Technikfolgen abschätzen lehren.* Edited by M. Dusseldorp, R. Beecroft. Wiesbaden: Springer VS. 11–35.

Beecroft, R., O. Parodi. 2016a. Reallabore als Orte der Nachhaltigkeitsforschung und Transformation. Einführung in den Schwerpunkt. *Technikfolgenabschätzung – Theorie und Praxis* 25/3: 4–8.

Beecroft, R., O. Parodi (Eds.). 2016b. Reallabore als Orte der Nachhaltigkeitsforschung und Transformation. *Technikfolgenabschätzung – Theorie und Praxis* 25/3: 4–51.

Fernandez-Gimenez, M., H. Ballard, V. Sturtevant 2008. Adaptive management and social learning in collaborative and community based monitoring: A study of five community-based forestry organizations in the western USA. *Ecology and Society* 13/2: 4.

Jonassen, D., S. Land (Eds.). 2012. *Theoretical foundations of learning environments.* London: Routledge.

Keen, M., V. Brown, R. Dyball. 2005. *Social learning in environmental management: Towards a sustainable future.* London: Earthscan.

Knorr-Cetina, K. 1999. *Epistemic cultures.* Cambridge, MA: Harvard University Press.

Kolb, D. A. 1984. *Experiential learning: Experience as the source of learning and development.* Englewood Cliffs, NJ: Prentice Hall.

Land, S. M., M. J. Hannafin, K. Oliver. 2012. Student-centered learning environments: Foundations, assumptions, design. In: *Theoretical foundations of learning environments.* Edited by D. Jonassen, S. Land. London: Routledge. 3–26.

Lave, J., E. Wenger. 1991. *Situated learning: Legitimate peripheral participation. Learning in doing.* Cambridge, UK: Cambridge University Press.

Meyer-Soylu, S., O. Parodi, H. Trenks, A. Seebacher. 2016. Das Reallabor als Partizipationskontinuum. Erfahrungen aus dem *Quartier Zukunft* und *Reallabor 131* in Karlsruhe. *Technikfolgenabschätzung – Theorie und Praxis* 25/3: 31–40.

Mezirow, J. 2000. Learning to think like an adult. Core concepts of transformation theory. In: *Learning as transformation: Critical perspectives on a theory in progress.* Edited by J. Mezirow. San Francisco: Jossey-Bass. 3–33.

Miller, T. et al. 2014. The future of sustainability science. *Sustainability Science* 9/2: 239–246.

Mochizuki, Y., M. Yarime 2016. Education for sustainable development and sustainability science. In: *Routledge handbook of higher education for sustainable development.* Edited by M. Barth, G. Michelsen, M. Rieckmann, I. Thomas. London: Routledge. 11–24.

Overdevest, C., A. Bleicher, M. Gross. 2010. The experimental turn in environmental sociology: Pragmatism and new forms of governance. In: *Environmental sociology.* Edited by M. Gross, H. Heinrichs. Dordrecht: Springer. 279–294.

Pahl-Wostl, C., M. Hare 2004. Processes of social learning in integrated resources management. *Journal of Community and Applied Social Psychology* 14/3: 193–206.

Pahl-Wostl, C., M. Craps, A. Dewulf, E. Mostert, D. Tabara, T. Taillieu. 2007. Social learning and water resources management. *Ecology and Society* 12/2: 5.

Parodi, O. et al. 2016a. The ABC of real-world lab methodology – From "action research" to "participation" and beyond. *Trialog* 126/127: 74–82.

Parodi, O. et al. 2016b. Von "Aktionsforschung" bis "Zielkonflikt". Schlüsselbegriffe der Reallaborforschung. *Technikfolgenabschätzung – Theorie und Praxis* 25/3: 9–18.

Parodi, O. et al. 2018. Insights into and recommendations from three real-world laboratories: An experience-based comparison. *GAIA* 27/S1: 52–59.

Schäpke, N., F. Stelzer, M. Bergmann, D. J. Lang. 2016. Tentative theses on transformative research in real-world laboratories: First insights from the accompanying research *ForReal*. *Technikfolgenabschätzung – Theorie und Praxis* 25/3: 45–51.

Schäpke, N. et al. 2017. *Reallabore im Kontext transformativer Forschung. Ansatzpunkte zur Konzeption und Einbettung in den internationalen Forschungsstand.* IETSR Discussion Papers in Transdisciplinary Sustainability Research 1. Lüneburg: Leuphana Universität Lüneburg.

Schäpke, N. et al. 2018. Jointly experimenting for transformation? Shaping real-world laboratories by comparing them. *GAIA* 27/S1: 85–96.

Schneidewind, U. 2014. Urbane Reallabore – ein Blick in die aktuelle Forschungswerkstatt. *pnd online* 3: 1–7.

Schneidewind, U., M. Singer-Brodowski. 2015. Vom experimentellen Lernen zum transformativen Experimentieren. Reallabore als Katalysator für eine lernende Gesellschaft auf dem Weg zu einer Nachhaltigeren Entwicklung. *Zeitschrift für Wirtschafts- und Unternehmensethik* 16/1: 10–23.

Trenks, H., C. Waitz, S. Meyer-Soylu, O. Parodi. Forthcoming. Mit einer Realexperimentreihe Impulse für soziale Innovationen setzen – Realexperimente initiieren, begleiten und beforschen. In: *Transdisziplinär und transformativ forschen. Eine Methodensammlung.* Edited by R. Defila, A. Di Giulio. Wiesbaden: Springer VS.

Waitz, C. et al. Forthcoming. Das Reallabor als Motor für Quartiersentwicklung – Erfahrungen aus dem Karlsruher Experimentierraum. Berichte. *Geographie und Landeskunde.*

WBGU (German Advisory Council on Global Change). 2016. *Humanity on the move: Unlocking the transformative power of cities.* Berlin: WBGU.

Wiek, A., B. Kay. 2015. Learning while transforming: Solution-oriented learning for urban sustainability in Phoenix, Arizona. *Current Opinion in Environmental Sustainability* 16: 29–36.

Wiek, A., D. J. Lang. 2016. Transformational sustainability research methodology. In: *Sustainability science.* Edited by H. Heinrichs, P. Martens, G. Michelsen, A. Wiek. Dordrecht: Springer. 31–41.

Wiek, A., L. Withycombe, C. L. Redman. 2011. Key competencies in sustainability. *Sustainability Science* 6/2: 203–218.

Wiek, A., A. Xiong, K. Brundiers, S. van der Leeuw. 2014. Integrating problem- and project-based learning into sustainability programs. *International Journal of Sustainability in Higher Education* 15/4: 431–449.

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