IOP Conf. Series: Earth and Environmental Science 1078 (2022) 012109 doi:10.1088/1755-1315/1078/1/012109

Real-world Laboratories in the Building Sector - Strategies for Transformation and Leap Innovations

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Abstract. The German Federal Environment Agency's (UBA) goal is a climate-neutral and resource-conserving building sector by latest 2050. To reach these targets radical innovation is needed in all areas from material and construction development to the lifecycle-compatible design and adaptability of entire buildings. To accelerate this kind of radical innovation in various areas of the economy, real-world laboratories or regulatory sandboxes are already employed. These are physical or theoretical spaces where legislative frameworks in targeted areas can be lowered or abolished – allowing researchers and businesses to operate in less restrictive regulatory environments. Real-world laboratories have the potential to function as what Schaepke and Steltzer call *transformative research* – research that drives societal change processes by transforming knowledge. In the building sector, this approach can facilitate the necessary rapid development of new material and construction techniques, while simultaneously valuing the communicative exchange and transfer processes through which these advances can be societally co-produced, validated and legitimized. Planning culture is plagued by outdated and often counterintuitive norms and regulations, making it extremely difficult and economically unviable to apply experimental techniques, materials, and approaches in real-world projects. In this context, the Real-world Laboratories model has great potential to drive innovation in the planning disciplines through new inter- and transdisciplinary approaches that can integrate actors from civil society at an early stage, thus anchoring newly produced knowledge and innovation in society. Universities are well placed to initiate and drive such processes. Especially in architecture training, projects with a strong link to real contexts, actors, and materials allow learners to access new understandings of how planning processes can function. By working on eye level with clients, administrators, lawmakers and those from other disciplines, a new blueprint for real practice can be developed. This paper analyses the characteristics of the Real-world Laboratory method specifically for the building sector. Principles to successfully implement the method in practice are derived from a series of transdisciplinary projects undertaken as part of the research, practice and teaching at Natural Building Lab, TU Berlin.

Keywords: real-word laboratories, building sector, leap innovation, transformation strategies

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1. The Emergence of Real-World Laboratories (dt. Reallabore)

In recent years the concept of real-world laboratories - RwLs (dt. Reallabore) has been increasingly present in the discourse surrounding sustainability-oriented research. Literature describes RwLs as a tool to foster transformative research – research that drives societal change processes by transforming knowledge [1] in the face of increasingly complex global challenges. Therein new forms of science-society collaboration play an important role [1] and it is proven that the early involvement of non-academic actors appears to benefit societal project outcomes [2]. In this sense, RwLs were introduced as 'places of experimentation and innovation, as incubators of a future reality' [3]. Here, the highly artificial environment of the laboratory intertwines with non-scientifically captured everyday reality and life. This becomes particularly important in the building sector as one of the key drivers towards a climate-friendly future: in 2020 buildings accounted for 36 percent of global energy-related CO2 emissions [4]. However, according to the German Federal Environment Agency (UBA), the goal of a climate-neutral and resource-conserving building sector needs to be achieved by the latest in 2050. To reach climate and resource targets in the building sector, radical innovation is needed in all areas from material and construction development to the lifecycle-compatible design and adaptability of entire buildings. [6]

1.1. *Definition and Research Gap*

The term and related format have their origins in the field of transformative sustainability research: the neologism "real-world laboratory" (or dt. Reallabor) was first introduced to science and literature in 2010 [8]. As an idea, it connects the contradictory concepts of the highly artificial and controlled laboratory with an inherently unpredictable everyday life [3]. The term also indicates that what is currently only (possible) in the laboratory could be a social reality in the future. RwLs therefore, are places of experimentation and innovation holding the potential to become incubators of future reality [6].

Real-life laboratories – directly linked to urban development, urban research, and urban transformation – were conceived as a framework for social research, transformation, and learning processes [11]. According to the German Federal Ministry for Economic Affairs and Climate Action digitisation, new technologies and business models are rapidly conquering areas of the economy and life. RwLs create adequate testing space for innovation and allow regulators to learn about the opportunities and risks associated with new discoveries and to develop appropriate solutions. Simultaneously RwLs provide an opportunity to strengthen social acceptance of these innovations. Thus, the broad understanding of RwLs in Germany has been mainly linked to the fields of technology, mobility, city planning, services, telemedicine and helped to foster innovation and progress in these specific fields [12].

It is becoming increasingly clear that technological progress alone will not be enough to solve increasingly wicked global challenges such as the climate emergency. Institutions on all scales are increasingly looking for new approaches to successfully shape the pending global and national societal transformation process that will enable sustainable development on all levels - also applying to the building sector. Here regulatory sandboxes have an equally thriving potential to enable the testing of innovative technologies, products, or approaches in a real-life environment, especially those which are not yet fully compliant with the existing legal and regulatory framework [12]. The relevance of RwLs in regards to fostering social and ecologic innovation in general can be witnessed as the method is getting embedded in political frameworks, such as the German coalition agreement of the federal government from 2021. The establishment of a law to enable RwLs settings as 'open spaces to test innovation' is part of the agreement [13]. Even though equally important and promising for a highly polluting building sector, a fairly small number of appropriate RwLs can be identified. With this paper, we would like to underline this research gap and call out the lack of RwLs in the Building Sector. As strategies and methods for transformation, they hold immense potential for leap innovation and progress towards a sustainable building and construction industry.

But what exactly are the characteristics of this method specifically for the Building Sector? How can RwLs in the sector become incubators for leap innovation and progress? What are the needed frameworks and principles to successfully implement the method? Under what circumstances can RwLs contribute to the positive transformation of the building sector?

2. The Characteristics of RwLs

In the following section, we will use the characteristics of RwLs in the context of transformative research developed by Schäpke et al. [1] as a basis to describe the concept of RwLs focusing on a transformation of the building sector. From there we will define a set of 6 method categories based on the definition of success factors by Bergmann et al. [5] that have been applied in four case studies that we have been involved in as part of our research and teaching practice at Natural Building Lab**,** TU Berlin.

In their paper 'Real-world laboratories in the context of transformative research' Schäpke et al. [1] state that a shared definition of real-world labs is lacking. Thus, they derive a set of five characteristics that we use as a basis for our investigation of RwLs in the context of transformation in the building sector. Namely, these are a) Focus on the interrelation of building sector and societal transformation, b) the experimentation via build prototypes and co-productive processes as a core research method, c) transdisciplinary planning processes as a core research method, d) transferability of RwL outcomes through reflection and learning.

2.1. Interrelation of the Building Sector and Societal Transformation

Today, transformation processes in the field of a transition towards sustainability are closely linked to societal challenges. To this effect, the WBGU report 'A world in transition' states that 'economy and society must urgently undergo a fundamental change to ensure the preservation of humankind's natural life-support systems and the prospects of humankind' [6]. Further climate change mitigation is described as one necessary element in this regard that is - along with loss of biodiversity, land degradation and water pollution amongst others - part of the 'earth system megatrends'. Apart from these global economic and social megatrends - such as e.g. development, democratisation, energy trends, urbanisation, and increasing land use contribute to the need for transformation and thus transformation-oriented research. In this regard, RwLs operate at the interface between transformation research and transformative research [1].

Regarding the interrelation of societal transformation and the building sector, RwLs can contribute to the level of systemic knowledge, orientation knowledge, and transformative knowledge. On the one hand, they put their focus on understanding and assessing sustainability problems in the building sector, on the other hand, they develop precise solutions [7]. On the level of systemic knowledge, they can contribute to the understanding of the interaction between the built environment and its economic, ecologic, and social context. This could be the interaction of the usage of resources, construction principles and economic constraints, or the use of land in relation to the effects on biodiversity. On the level of orientation knowledge, they help to consider the implications and effects of the buildings sector today, as well as potentials and challenges for the future. This could for example refer to the Life Cycle Assessment (LCA) of buildings or regulations and norms for building materials. On the level of transformative knowledge RwLs help to gain an understanding of tools and mechanisms that need to be applied to foster transformation in the building sector. This could refer to alternative planning processes with a focus on the participation of future users or the embedment of extended training opportunities on circular construction principles for craftsmen.

2.2. Experimentation via Build Prototypes and Co-productive Processes as a Core Research Method

It is crucial for RwLs to explore and trigger transformation processes through developing and testing solutions - in other words, experimentation [1]. According to Schneidewind [8] RwLs aim to turn the negative connotation of the term "experiment" into a positive one - it describes RwLs as places of targeted (and at least partly controlled) experiments in real-world settings. The respective "real experiments" are not supposed to reproduce the special world of scientific laboratories, rather represent the unpredictable nature of society. They provide a specific setting for experiments in terms of time, local context, and resources.

In the building sector, RwLs can include an experimental component via built prototypes and co-productive planning processes, that would otherwise not have been undertaken. Monitoring and evaluation tools have become a crucial component in this field. They are integral parts of an iterative knowledge gain via experimentation. Through targeted testing and improvement of e.g. building materials, construction techniques or process formats improvement related to specific research questions is achieved.

2.3. Transdisciplinary Planning Processes as a Core Research Method

In RwLs actors with different backgrounds should collaborate to develop applicable and scientifically proven solutions to sustainability problems producing scientific results and insights in the process. Thereby 'different ways of knowing' apply, where planners generate knowledge through dialogue and experience, learning from local knowledge, interpretation of symbolic and non-verbal signs, and their own reflection [9]. Thus, knowledge from different disciplines, scientific and experience-based knowledge are combined and contribute to the development of integrated solutions in a transdisciplinary research mode.

Using the core requirements of a transdisciplinary research mode as formulated by Lang et al. [10] as a basis, the application of transdisciplinary research RwLs focusing on the building sector can be discussed under three categories: firstly the focus of the RwLs on topics of societal importance (see above: focus on the interrelation of the building sector and societal transformation). Secondly, the facilitation of a mutual learning process for actors from different disciplines as well as non-academic actors. This is especially true in the face of the complexity that characterizes contemporary building projects in regions like Central Europe. As built prototypes and co-productive processes are a core research method (see above), a collaboration of academia, craftsmanship, industry, and civil society becomes obligatory. Third, is the creation of a societal robust, solution-based knowledge, which is connecting the building sector to questions of societal and scientific relevance.

2.4. Transferability of RwL Outcomes through Reflection and Learning

RwLs in the building sector aim to contribute to a transformation towards sustainability via precise built contributions or interventions. These prototypes are most often laid out with a long-term perspective and are embedded in long-term processes. They will stay, even if the associated research project ends. The interface between academic and non-academic contexts usually requires that projects are embedded in a network of supporting actors, linked to people that have taken on responsibility and have been developed in a way to test financial support structures as well as legal regulations, and are integrated into university structures. This is especially true for Rwls where learning processes are an integral part. They offer a long-term testing field for investigation and development for researchers and students if reflection plays a major role in the process.

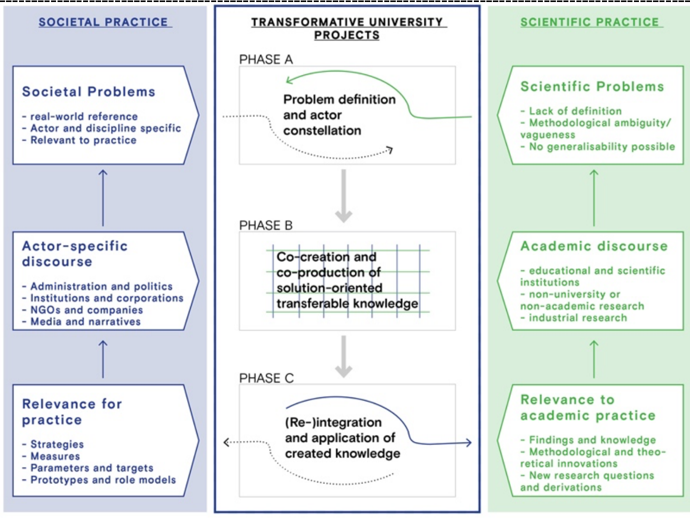

Figure 1: Characteristic interrelations in RwLs

3. Academic Learning Formats as Testing-grounds for Leap Innovation in the Building Sector

In the building sector-specific interpretation of the RwL approach, the definition of the necessary experimental spaces and framework conditions seems to be one of the greatest challenges. However, creative freedom on planning, legal and economic levels is essential for linking building and applied research with the building practice. Based on our research, teaching and practice the paper investigated whether projects at the interface of practice and academia (scientific research and teaching) can function as such free and creative experimental spaces for the highly regulated building sector?

In the following section, four projects from Natural Building Lab's teaching and research context will serve as case studies. After a short introduction to the specific context and project, the applied principles based on the specific examples will be elaborated. The chosen projects apply to all RwL characteristics, following experimental and transformative approaches in the planning and building process.

Natural Building Lab operates as part of a transdisciplinary network undertaking projects that produce knowledge and built prototypes for a post-fossil society. In the face of planetary boundaries, we are convinced that climate- and resource-adapted, circular building systems using renewable or reused building materials and healthy low-tech buildings with climate-active natural building materials will enable a future-oriented building culture. At the interface between academic and non-academic environments, we develop applied projects and solutions within our practice, research and teaching. These pursue holistic and public welfare-oriented principles and are developed in transdisciplinary processes in architectural education and production from the dialogue with other disciplines, the crafts and society.

Given the high complexity of construction projects, our participant perspective ensures important insights into project procedures and processes that are generally missing in neutral reporting. It is precisely this informal process-knowledge of mistakes and lessons learned that hold great transformation potential. With a view to validation, legitimacy, transferability, and scalability of the findings, scientific observation and recording are equally important. In order to fully exploit the potentials and project-generated knowledge a combination of both levels of reflection is necessary to draw an almost complete understanding and image of the systematic dependencies in the building sector.

3.1. *Project "Museum Pavilion and Knowledge Trails", TU Berlin (in the following: Museum)*
As a cooperation between the TU Berlin and the district of Charlottenburg-Wilmersdorf the project "Pavillon und Wissenspfade" aims to enhance the link between university and city. To do so an exhibition pavilion and landscape plan are to be developed on the southern parts of the campus by 2026. Contrary to common public planning processes and architecture competitions, the project is conceptualised in a participatory and transdisciplinary process from within the university. It is thus intended to become an innovative model project for ecologically sustainable and climate-friendly planning and building practice.

3.2. *Infozentrale Berlin (in the following: Infocenter)*
In cooperation with an EU-funded research project, a group of architecture students planned and implemented a circular building from waste materials as an infocenter on the Rollberg site in Berlin-Neukölln. With limited means and resources, innovative solutions and new building materials needed to be developed to reach the goal of a resource-positive construction in an urban context that embodies a new method of architectural production for a post-consumer society. The pavillon is today used by a diverse set of actors active on site, showcasing up-to-date information about the currently active processes and local developments. The project creates a place for involved actors to encounter each other and the neighborhood.

3.3. *Multifunctional Building Preußenpark Berlin (in the following: Park project)*
The 55000 sqm Preußenpark is located on the north side of Fehrbelliner Platz in Berlin Charlottenburg-Wilmersdorf. In the context of the public redesign and redevelopment project of the inner-city park, the regulation of the previously merely tolerated streetfood market "Thai-Park" is an essential component. To create the necessary market infrastructure a multifunctional building is required. The redesign of the park is highly conflictual as is the construction of the multifunctional building. Thus, the project focus is to embed a planning process that answers to the needs of conflicting actor groups and serves as an example for a biodiversity-friendly, resource-positive building and climate-adaption of urban spaces. The district of Charlottenburg-Wilmersdorf is considering a combined use of the multifunctional building for market operations and district services.

3.4. *North-South Collaboration Project in an Informal Neighbourhood (in the following: Neighbourhood project)*
A long-term coalition of academic and non-academic partners from Colombia and Germany and the neighborhood Moravia in Medellín, Colombia that has developed informally is working to design and undergo a transformation process of the neighborhood that is answering to the needs of the community in face of relocation processes. In various multidisciplinary and intercultural formats, diverse stakeholders meet on site to discuss, design and build and thus foster the co-production of livable urban spaces.

4. **Principles for RwLs for Leap Innovation in the Building Sector**
The following paragraph refers to RwL success factors as defined by Schaepke et al. [5] and defines building sector-specific principles for a positive science-society collaboration within this field. These principles derive from the above-mentioned case studies and academic teaching context. Thus, they can be understood as a recommendation for a transformation process towards sustainability. These principles serve as an orientation rather than step-by-step instructions and will have to be adapted to other contexts.

Principle 1: Development and Practice of a Balanced Collaboration Culture between Science and Society

For a productive collaboration between different groups of actors, attention and consideration of everyone's needs are essential. This must be ensured at every stage of the project, from the development of the project proposal, through implementation, to evaluation and joint reflection. Only in this way can the experience of collaboration positively influence mutual understanding, collective goals, participation, and ultimately a social relevance of the research. [5]

By embedding the above-mentioned RwLs in academic teaching and learning contexts, partial relief from limiting stress factors is made possible, such as the direct scientific pressure to exploit. In the Museum project individual and collective learning experiences became tools for shaping and evaluating planning processes that take place, and these become research topics and fields of experimentation. In the Park Project a balanced collaboration culture can assist in overcoming prejudices towards the project in terms of sealing of green space and collectively target public concerns and interests.

Figure 2: Learning conference and workshop during the Museum project (photographer: Matthew Crabbe, Natural Building Lab)

Principle 2: Realistic Assessment of Necessary (time, monetary and human) Resources
The success of a RwL is directly dependent on the motivation and commitment of the involved actors, both on the project and participants' site. In this regard, realistic goals and milestones must be defined and adjusted when needed so that regular successes on a short- and long-term basis can be achieved. It is important to observe the process from the start to pick up relevant questions, problems and topics, this allows participants to be able to react immediately to changing conditions. Especially within heterogeneous teams, the satisfaction of the participants strongly depends on the compatibility of external circumstances and internal topics such as timetables and individual availability, tasks and personal expectations, the project process and group dynamic. [5]

In the Infocenter project, the discrepancy between the anticipated and actual amount of work and time was particularly present - project management soon became an essential task. Short and long term logistical challenges had to be solved at all levels of the project to manage the contribution of material, human and financial resources. By being in charge, students were empowered to act independently and expanded their field of responsibilities. At this point, we find it important to say that the participants' flexibility cannot be taken for granted. To prevent discontent and avoid stressful situations due to short planning perspectives, a realistic assessment of necessary resources and effort is essential.

Principle 3: Embrace experimentation as a method for leap innovation

According to Bergmann et al. [5] experimentation is an integral part of RwLs, the nature of this experimentation depends on the specific project context. Characteristically, the experiment consists of a thesis and corresponding intervention, observation, analysis and evaluation of the effects as well as the drawing of conclusions on elementary aspects. All phases are prepared, organized, moderated and monitored by the researchers in collaboration with involved actors. The Federal Ministry of Economics and Climate Protection states that RwLs as test spaces enable innovative approaches to be tried out under real conditions that are only partially compatible with the existing legal and regulatory framework [12].

The results of these temporally and spatially limited experimental spaces in the building sector provide the basis for a context-specific and well-informed suspension of normally very strict building regulations and industry standards, the resulting space for experimentation new regulations to be developed based on evidence.

For example, in the Infocenter and Neighborhood projects new building materials from waste as well as sophisticated constructions and hybrid solutions made of reused and new wood were being investigated and developed. Different prototypes up to a 1:1 scale of structural systems and demonstrators have been developed, tested, and evaluated. Parts of the findings were later implemented in the realization of the projects.

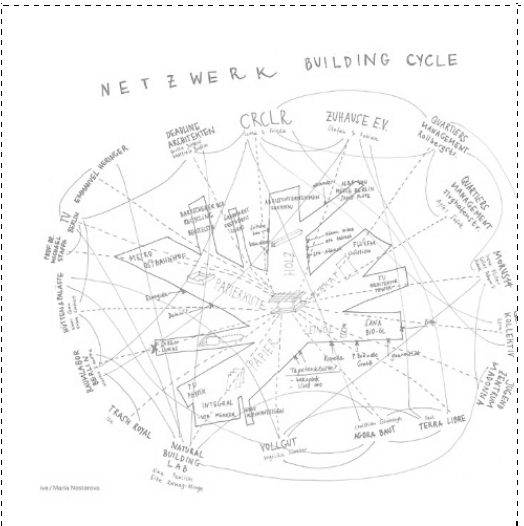

Figure 3: Network created within the Infocenter project
(Illustration: Maria Nesterova, Design Studio Building Cycle, NBL TU Berlin, WiSe 2017/18)

Figure 4: Construction works on the prototype during the Infocenter project
(photographer: Eike Roswag-Klinge, Natural Building Lab)

Principle 4: Implementation of New Communication Methods and Skills

Clear communication on all levels is indispensable for the necessary transparency of processes. As Bergmann et al. [5] point out in the 4th success factor, this requires new communication formats that are to be developed in cooperation with the involved actors and applied regularly. This must be done in a low-threshold manner which requires an expansion of the typical skillset required from a researcher. Above all, a clear address and place of communication are important, to ensure sufficient reach outside academic scientific circles. The connection between a project and a specific site establishes a needed infrastructure to locate the project and the emerging discourse in a visible and public way.

For the building sector, long-term RwLs can become a method for early and continuous participation of a broader public in planning processes. Open communication of the planned phases and content ensures the necessary transparency. In the Museum project, the early activation of the building site is intended to create a timely and serious discourse that allows everyone to become part of the project and to address concerns at an early stage. In the Neighborhood project, it became clear that sufficient time and space are necessary for these processes. Personal interaction, increased public attention, and resulting participation built up trust and commitment among participants.

Principle 5: Facilitating Lasting Impact and Transferability by providing Research-Based Learning and Reflection.

RwLs provide an opportunity for mutual knowledge production connecting scientists, practitioners, and society. Through close cooperation with practitioners, scientists gain new, practical perspectives and knowledge that allows them to reflect themselves in new ways [5]. The same applies to students who are often involved in RwLs as part of their academic learning process. Theory-based evaluation criteria create a possibility to compare different experiments. To assess the outcomes of RwLs, long-term stability and transfer potential have proven to be important factors that distinguish successful projects from local, singular, and short-lived projects [5]. For this constant reflection also plays a major role.

As part of the Park project, a study of the potential for the reuse of resources of existing non-used building stock was commissioned. Together with the Park project itself and its focus on circular construction principles, embedding this study provides the possibility of knowledge transfer between NBL RwLs, e.g. the Museum project where similar design principles apply.

Figure 5: Workshop during the Museum project (photographer: Matthew Crabbe, Natural Building Lab)

Principle 6: Real-world context creates dependencies and constant need for adaptability
By their nature, RwLs operate on the interface between academic and non-academic environments. As part of their transdisciplinary research setting, factors that lead to the need for adaptability are indispensable. Rather than failure, these adaptations - and even more importantly the process that has led to these adaptations - can be seen as project outputs. Thus, Bergman et al. [5] consider flexibility and adaptability as a prerequisite for successful collaboration in RwLs. As a consequence, they call for recursiveness and self-reflection to answer to ever-changing goals, contents, actors, and processes. Thus, the real value is a learning process on adapting goals, procedures, and dialogue partners.

A strong dependency on external factors that influenced the design process is what we are currently dealing with in the Museum project. These are namely the strict requirements of the funding scheme for the building project that includes the programmatic design of the pavilion that the project constantly has to adapt to in alignment with the actors involved. A constant need for adaptability is also what we are facing in the Infocenter project. As a built prototype with exterior walls that are made out of stacked cardboard boxes vandalism and external influences made it necessary on various occasions to physically adapt and improve the project.

5. Conclusion

RwLs offer great potential to drive innovation in the construction sector if they are carefully designed, implemented, and monitored. Therefore, the inclusion of teaching and learning formats provides an excellent opportunity to do this, where the iterative practice of reflection is methodologically inscribed.

In other fields the importance and acknowledgment of the potential of RwLs is significantly higher than in the building sector. Highly competitive systems lead to an almost constant striving for innovation and improvement. Even though the underlying economic motives have to be criticized, they lead to an increased willingness to experiment. Real-world experiments are essential for serious testing and sustainable establishment of progressive ideas, as they enable a methodical and thus also legal framework.

The profound transformation in the building sector is no longer just the ethically correct aim, but the only possibility. This requires courage, innovation, and spaces of experimentation in which the necessary advances for leap innovation are tested and developed. In contrast to the highly regulated building sector, there is an acute need for spaces that are fast, free, creative and radical, where certain regulatory constraints are paused in order to develop creative solutions. Teaching formats and academic learning environments offer such spaces and manifest important interfaces to science and research. Here, the teaching and learning space can be an incubator for innovation in practice. Another benefactor of the transdisciplinary and participatory approaches of RwLs is the early integration of the new generation of planers though a direct active engagement with the pressing questions of the future. The foundation for a sustainable approach must be laid as early as possible so that the individual learning experience can evolve to a collective advantage. Thus, processes must be understood as places of action and a field of research. New adequate formats such as RwLs lay the foundation of transformative research and change.

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