Experiment

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Definition

The (scientific) experiment (lat. *expĕrīmentum* "proof, trial, test" and "experience", Lewis and Short 2020, 403) is a creative, useful, fundamental, systematic empirical method to gain knowledge. With the Enlightenment, experiments were used in the classical experimental sciences of chemistry and physics (Franklin and Perovic 2021). Since then, they have evolved into an essential source of scientific knowledge in almost all disciplines. The experiment is a tool for exploring the new. But unlike mere observation, it involves an intended manipulation of the observed system. As a connecting element, it further allows integrating different research approaches of various disciplines into a methodological context, thus promoting inter- and transdisciplinary processes (West 2021).

Steinle (1997) distinguishes hypothesis-driven or confirmatory from exploratory experimentation. While the former designates concrete hypotheses as true or false and reflects the dominant scientific model of critical rationalism (Popper 2013), explorative experiments are more suitable for generating hypotheses in unknown contexts and deriving rules inductively. Their epistemological importance is often underestimated, which changes with the "experimental turn" (Overdevest et al. 2010; West 2018) of the humanities and social sciences: experiments are now valued as a scientific method even under uncertain, uncontrollable conditions, recognizing complexity and conflict between knowledge and ignorance. For art, architecture, and design, explorative experiments have always been fundamental. They often become an open-ended creative-artistic intervention, generating astonishment, amazement, or even snubs in society with the aim of triggering reflections and (re)action. In the social sciences, psychology, and medicine, distinction is made between laboratory and field experiments. In quantitative studies the limited reproducibility of the less controllable field trials is often compensated by statistical methods.

The thought experiment has a long tradition in philosophy and natural sciences. By making counterfactual assumptions that are difficult or impossible to establish in reality, researchers check whether a theory is consistent or leads to para-

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doxical situations. "Schrödinger's cat" (Schrödinger 1935, 812, 827; Trimmer 1980, 323–38) – hypothetically placed in a special box – would be dead and alive at the same time according to the laws of quantum mechanics, until the observer opens the box. Exploratory thought experiments can help refine or illustrate theories (Steinle 1997) and utopias (West 2019, 2021; West and Kück 2019). Virtual experiments (Pasemann 2017, 9) in theoretical physics and mathematics often represent numerical computer simulations under model assumptions which could hardly be achieved in reality and are popular in natural and engineering sciences (Böttger et al. 2019), architecture, and social sciences. Explorative thought experiments are gaining importance in transdisciplinary contexts. Distinctions between "qualitative" and "quantitative" experiments in social sciences (Kleining and Witt 2001) refer back to the qualitative and quantitative methods in empirical social research.

In research practice uniform categories of experimentation exist neither in general nor within individual disciplines. The narrative of a clearly defined procedure of experimentation has to be understood as a consequence of canonized reporting, which in publications and textbooks intentionally ignores the temporal and causal de facto course of the research process, obscuring the actual research strategy *a posteriori*. In teaching, dealing with uncertain evidence and the problem of stabilizing experimental systems are largely avoided, for example in physics lessons (Ruhrig and Höttecke 2015). Rheinberger (1998, 287–88) comes to a similar conclusion, considering the research process as a system. He designs experimental cultures as an epistemology of modern experimentation, based on experimental systems as the smallest functional research units. The underlying concept of culture implies that scientific knowledge itself is not independent of its own history. Less planning and control, more improvisation and coincidence characterize everyday research.

Exploratory field experiments as well as real-world experimentations, e.g. designed as interventions in urban public space, even make it possible to cross the boundaries of science into society in a transdisciplinary manner: not just as an artistic or scientific act, but as a process in which everyday and specialist knowledge are negotiated on an equal footing. With "real-world experiments", a category of transdisciplinary field experiments has recently emerged which do not take place in scientific laboratories, but in and with society (Ehnert 2023; Gross and Hoffmann-Riem 2005; Scholl et al. 2018), where conditions can change in an unforeseeable way.

The orientation on uncertain knowledge is central to more recent approaches, including the concept of real-world experiments which can structure how we deal with uncertainty and ignorance. Due to its grounding in real life and open-ended results, the distinctions between research, teaching, learning, and (inter)action blur: the aim of the experiment then follows not only research logics, but also logics and demands of the "real-world".

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The term *real-world experiment* is particularly used in the context of real-world laboratories, which, as an experimental format, have a transdisciplinary setting of institutional, civil society, and scientific actors and address a transdisciplinary objective jointly selected through processes of co-design of the questions, co-production of knowledge for transformation at eye level, and co-evaluation (West and Kück 2019). They differ from related methods of participatory action research (Chevalier and Buckles 2019), intervention research, or transdisciplinary cooperative research (case study approach, research-based learning) by their "twofold transdisciplinary ambition": Firstly, the phases of conceptual development require a co-design of a thought experiment in a transdisciplinary team. Secondly, the implementation and observation of the transformative experiment itself creates application knowledge in a second transdisciplinary context. Due to their orientation on uncertainty, transdisciplinary experiments create spaces for improvisation and reflection, following a reasoning which is transversal, creating "transtopias" (West 2019, 2023).

Background

The future is glocal – global and local at the same time: Global challenges like anthropogenic warming, loss of biodiversity, etc. require local answers and overall societal future-oriented, sustainable transformation and innovation processes, right up to a new social contract. In this sense, the Paris Agreement on climate change (UNFCCC 2015) should not only function as a climate agreement, but also as the basis for a new, integrative, and inclusive agenda of development – the 21st century's social contract. These challenges cannot be mastered only through technical–technological innovations (West 2023): In addition to changes in institutional, regulatory, and political structures, new inter- and transdisciplinary actor constellations and transgressive processes are required, which arise from a transversal individual basic orientation and a transition between different forms of action and reality constellations, across prevailing categories and differences (West 2019).

Research and teaching play a key role in the justification of these transformation processes, as passing from the industrial to the knowledge society, the mode of learning, knowledge generation, and regime changes: knowledge is increasingly generated de-centrally, new places and actors are added, which enable production and recombination of different types of knowledge in new, temporary, experimental constellations and cooperation. Thus, concepts of knowledge change: in addition to individual, solitary recognition, social, jointly generated, inter- and transdisciplinary knowledge is gaining importance. Knowledge, the recognition of ignorance, and uncertainty become transformative energy. Individual and collective innovation and transformation processes are often triggered less by cognitive knowledge than by life-world-motivated needs for change and reform, which can be commu-

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nicated and implemented in an exploratory, improvisational, experimental way (Epstein 1994, 711; WBGU 2011, 242; West 2019, 2023), whereby reflexivity increases. The (future) *modus operandi* of knowledge societies can then be understood as continuous experimentation, in which scientifically and socially defined problems can hardly be separated (Välimaa and Hoffman 2008; Vilsmaier et al. 2017; West 2023).

The experimental turn in the knowledge society marks the moment when transdisciplinary knowledge generated through experiments becomes the guiding principle for action. Hereby scientific and everyday knowledge are addressed. At the same time, existing knowledge, patterns and schemes of meaning, interpretation and hegemonic practices, social structures and schemes of order are questioned, reflecting on ways of life and seeking options for action and solutions to "wicked problems" (West 2018, 330). This is also reflected in the discussion on "real-world experiments". As a hybrid form of experiment, they oscillate between modes of "knowledge generation", "knowledge application", "controlled" and "situation-specific" boundary conditions that cannot be fully controlled (Schneidewind 2014, 2). Experiments initiate a transition from explorative-improvised action to cognitive insights, if all participants can bear complexity and a temporary loss of control. With the experimental turn, science changes towards *Mode 3*, emphasizing the coexistence and co-development of diverse knowledge and innovation modes (Carayannis et al. 2012), and opens up new perspectives, places, and spaces for public science. By integrating different bodies and systems of knowledge, multiple transdisciplinary teaching and learning processes are released that generate socially robust knowledge for transformation, increase the reflexivity of the actors, and change social rationalities and cultural and disciplinary practices. In experiments, the connection between scientific and everyday learning changes. The knowledge society is an experimental society.

Debate and criticism

Doubts are expressed whether future-oriented sustainable development can be addressed at all through transdisciplinary experiments in science, research, and teaching. The added value that can be generated is also controversial. Criticism primarily concerns (1) *methodological requirements* students and lecturers face, (2) problems of *integrating* transdisciplinary experiments into disciplinary teaching and research curricula, (3) a strong *focus on the Western or European cultural and political context*, and (4) the fundamental scientific *self-conception* on which transformative science is based.

A high degree of openness to results is inherent in transdisciplinary experiments, as in a transdisciplinary environment, project or learning content and corresponding methods cannot be anticipated precisely and in detail. Considering

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the lack of acceptance of transdisciplinary methods within the disciplines, missing evaluation methods and structures, transdisciplinary research and teaching often do not fit well into academic curricular structures. The "twofold transformation ambition", which is directed outwards (society) and inwards (the scientific system), holds the risk of overstraining research activity (Jaeger-Erben et al. 2018, 117). Whether curricular goals can be achieved at all becomes a problem when academic qualification is envisaged within transdisciplinary projects.

Criticism arises about the cultural context: Developed in the Western hemisphere, transdisciplinary research and experimentation have only recently been applied to other regions. Even if in line with the objective of transdisciplinarity, problems have been encountered in application. Sim et al. (2019) focus on *guanxi* (relationships) in the local context of China – pointing to the importance of state adjudication in knowledge production. In the Western context, "relationship" has been discussed as "complicity" (Ziemer 2016) in experimental space appropriation processes. Schmidt and Neuburger (2017) allude to the importance of North–South imbalances in power relations in the application of transdisciplinary research and thus to processes in and through which space is appropriated, constituted, and manifested (West 2019).

Regarding space, most applications have dealt with macro-physical phenomena like earthquakes, climate change, and sustainable land-use management. Seldom has research focused on phenomena such as development in a city, neighborhood, or community (Schmidt and Neuburger 2017; Sim et al. 2019). Thus, the time is ripe to initiate research on understanding the mutual interaction of processes as real-world experiments in a city like Hong Kong. Transdisciplinary transformative formats are often claimed to have a normative character resulting from the specification of social goals, which blurs the scientific view. Grunwald (2018, 114) argues it is sufficient to explicit one's own normativity in the scientific discourse. In contrast, West (2019, 2023) sees sustainability as itself founded in the transdisciplinary experimental format and thus not as a normative goal.

Current forms of implementation in higher education

While the didactic implementation of disciplinary experiments usually follows rules and forms of the respective disciplines, individual attempts at standardization can be seen for transdisciplinary experiments. But efforts towards canonization are still absent. In transdisciplinary experiments, the paradigm of the knowledge society (Castelfranchi 2007; Välimaa and Hoffman 2008) moves towards a Mode 3 science (Carayannis et al. 2012) through collaborative learning, working, designing, and experimenting. The relation between teachers and students changes, since the participants alternately find themselves in the situation of the respective other.

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Transdisciplinary experiments oscillate between two work modes (Figures 1 and 2), which results in different didactic challenges. In the mode of integration (Figure 1), questions from different contexts are linked with one experiment, so that both disciplinary and transdisciplinary methods are further developed. In the mode of addition (Figure 2), different experimental elements, techniques, interventions, methods, and formats are used in a common thematic context. Thus, the integration mode is more research-oriented, while the addition mode is rather a tool. In practice, both modes are often intertwined or combined in varying degrees. The transdisciplinary experiment can be divided into two experimental phases. Firstly, the reflection and development of the scientific and everyday context of the experiment can be described as an exploratory thought experiment. Secondly, its implementation and the observation of its effects in society constitute a real-world experiment. The mode of both experimental phases is transdisciplinary, on different levels, which is why all persons involved must be open-minded and engage with the unforeseeable on both levels. This "twofold transdisciplinarity ambition" challenges or overstresses teachers and learners, but also activates unexploited learning potentials.

Possible forms of didactic transdisciplinary experiments can be illustrated by three formats: (1) *Knowledge to go* (West 2018) is an experimental teaching and research format in which transdisciplinary work is conveyed. The conception phase in the seminar room becomes an explorative thought experiment. The scientific and social conditions, basic hypotheses, and implications of possible interventions are developed in different context levels in the mode of integration (Figure 1) together with transdisciplinary partners. With the real-world experiment, the hypotheses are checked and the results from the various thematic and spatial context levels are brought together and discussed publicly with experts and transdisciplinary audiences. Learning and teaching are understood as active, self-controlled, situational, communicative, improvisational processes – a new transversal learning culture is implemented (West 2019). Similar, comparable concepts of using real-world experiments as a transdisciplinary teaching format have recently been developed in the field of sustainable mobility culture (Baum et al. 2021). (2) The *UrbanUtopiaLAB|Experimenting Utopia: Past … Present … Future* (West and Kück 2019) is an iterative multi-phase format for research and teaching that structures and supports comprehensive transdisciplinary transformation processes from utopia to policy advice. Experiments are combined in the mode of addition (Figure 2). Exploratory thought experiments are supported by techniques such as emo-action mapping (West and Kück 2019, 268) and combined with real-world experiments. In this way, joint intentional utopias emerge which are iteratively developed and evaluated in subsequent phases of observation, analysis, intervention, and political participation.

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Figure 1. Mode of integration: integrative transdisciplinary experimentation

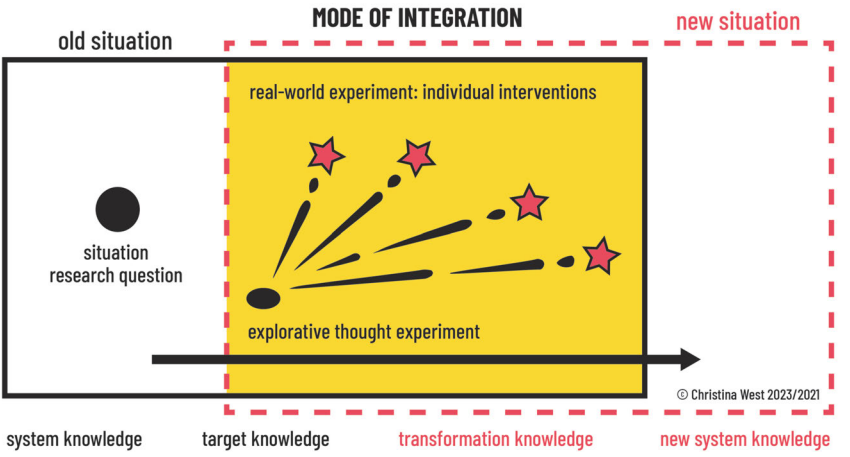
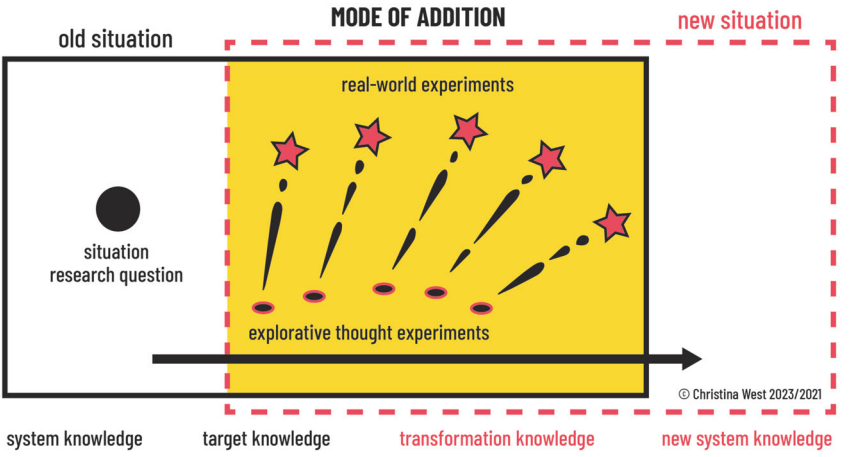


Figure 2. Mode of addition: additive transdisciplinary experimentation



Design: Christina West, based on West and Kück 2019, 272; West 2021.

(3) In Hong Kong, similar formats attempt to put *sustainability as a process* (West 2019), for which cultural specificities must be recognized: Hong Kong, a British colony for 150 years before returning to the sovereignty of China, is still intertwined with modernity and nationalism, and embedded in the Chinese land question. This applies to the understanding of and attitude towards imagination and practicing sustainable development and transformative transdisciplinary experimentation. Utility, efficiency, and productivity have been emphasized at the expense of equality, equity, and environmental sustainability. Relevant for

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sustainable development is opening up the mindset of students in a transversal, sustainable way. Two considerations on transdisciplinary transformative experiments emerge under these conditions: The first relates to contents of urban sustainability. Tang (2017) coined the concept of hegemonic-cum-alienated urban redevelopment, which considers the historical colonial base of Hong Kong's landed and property relations, with its processes and concretized patterns. The effect of redevelopment is more complex than "gentrification" – a displacement of the working class by the gentry (Glass 1964). Interventions in Hong Kong as a "real-world experiment in and through space" aim to dwell on its subtleties with a more accurate and inclusive elaboration. Opening up mindsets by transdisciplinary transformative experiments and interventions effectively and efficiently, field trips to different neighborhoods enable students to explore and learn in an experimental approach. Accordingly, they develop a critical attitude towards society and the environment. Sustainability is an experimental process that is to be achieved as people live their lives. A first step is to get acquainted with the neighborhood. Library research enhances their understanding of the forces producing the neighborhood's historical development. This is the prerequisite for reflecting on the issue of development of the city as a whole. At the end of the field trip, in a group discussion, students are requested to reflect on and talk about their experience. It appears that once equipped with the briefing on the ground, they start to change their perception of the neighborhoods and ponder about Hong Kong urban society. All feedback is used at the university for discussing ways to improve. The results of this reflection form the basis to update the experimental approach and organization of further experimental field trips. Discussion among students, teachers, instructors, etc. improved their understanding of Hong Kong's development.

The three discussed formats are archetypical and not limited to any regional context or actor constellation. Their application in practice with regional as well as international groups show – even if conducted under very different conditions and restrictions – that experiments, if they are applied in a genuine transdisciplinary setting, can indeed enable gaps to be bridged between disciplines and between different cultures and fundamental ways of thinking: By oscillating in different modes between thought and real experiment (Figures 1 and 2), building up new common epistemologies will be fostered (and even required!), and transversal thinking will emerge.

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