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DOI
10.1007/s10668-022-02659-y

Publication date
2022

Document Version
Final published version

Published in
Environment, Development and Sustainability

Environment, Development and Sustainability
https://doi.org/10.1007/s10668-022-02659-y

S.I. : TRANSFORMATIVE LEARNING FOR URBAN SUSTAINABILITY

Designing interventions for sustainable change in a real-world laboratory

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Received: 21 February 2021 / Accepted: 30 August 2022

Abstract
Real-world laboratories (RWL) aim to support transformations for sustainable urban development by producing outputs with practical and scientific relevance. To achieve these aims, the local community of which the RWL is a part should be in close collaboration from the start of a project. RWLs offer spaces for 'thinking outside the box' and for experimenting with new ideas through concrete interventions into the life world of the community. We provide methodological guidance for researchers on how to design interventions in RWLs that both affect change on the ground and contribute to scientific knowledge. This includes addressing issues important to local communities and generating transformation knowledge about how sustainable urban development can be actualised. We use the case of a project-based master's course within an RWL in the city of Zurich in Switzerland to demonstrate how the use of design thinking supported the development of needs-based interventions, curbing emissions from food consumption while aiming to generate scientifically relevant output. We conclude that further improvements in methodology are needed in order to test the effectiveness of interventions. However, the outputs of the approach show its potential both for having an impact in the real world and building on existing academic concepts for advancing transformation knowledge.

Keywords Real-world laboratories · Interventions · Transdisciplinary research · Design thinking · Transdisciplinarity · Urban sustainability transformation

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Published online: 13 September 2022

1 Introduction

Confronting the global crisis of climate change requires deep and sustained changes in behaviour and mindsets across society (Gifford et al., 2011; Goldberg et al., 2020). Societal transformation of this scale requires both global, top-down support and local, bottom-up action to succeed (Feola, 2015). Real-world laboratories (RWLs) are a mode of research-supported action focusing on the bottom-up, local action, offering spaces for 'thinking outside the box' and for experimenting with new ideas through concrete interventions into the life world of the community (Baden-Württemberg, 2013; Jahn & Keil, 2016; Wagner & Grunwald, 2019). Interventions describe activities within RWLs that are systematically developed, implemented and analysed (Parodi et al., 2016; Schäpke et al., 2018). An intervention includes an activity that facilitates transformation for sustainable development as well as the study of its effect in terms of triggering change. In line with the principle of a science-society collaboration throughout the process of transdisciplinary research (Lang et al., 2012), an intervention is developed, initiated, supported and implemented through researchers being in close collaboration with the community. Such interventions should be based on the needs of the community, rather than imposed by outside forces. They also provide a means of challenging current practices and experiencing transformation so that change is visible and demonstrated to be possible. RWLs can also contribute by producing transformation knowledge and providing real-world solutions for sustainability problems (Parodi et al., 2018; Wiek & Lang, 2016). Transformation knowledge is knowledge of how an intended change or target can be achieved. Producing such knowledge requires either observing an ongoing transformation or inducing a transformation through an intervention (Pohl & Hadorn, 2007). It is therefore important that the outcomes of RWL interventions can provide evidence on what supports transformation and under what conditions it can occur effectively. Without the accumulation of such knowledge and practical experience, knowledge sharing and analysis across different cases could be hindered, as results from interventions in RWLs are often highly context specific (Heiskanen et al., 2018; Schäpke et al., 2018; Wanner et al., 2018).

While several scholars have discussed the importance of using transdisciplinary methods during the establishment of RWLs (Menny et al., 2018; Parodi et al., 2018), a discussion of how such methods can be used to design and analyse interventions has so far been neglected. In this paper, we describe how a design thinking approach is adapted for a transdisciplinary learning setting to create RWL interventions. The project-based master's course 'Reallabor Hunzikerareal – nachhaltiges Verhalten fördern' is an RWL within a sustainable housing cooperative in the city of Zurich, in place to illustrate how students use a design thinking approach to create needs-based and evidence-based interventions. First, we introduce the concept of design thinking as a way of developing interventions in RWLs. Second, we show how the students use scientific theories and empirical studies to help shape the interventions and test their effects.

1.1 Designing needs-based interventions

Design thinking emerged originally as an approach to creating innovative products (Arnold, 2016; McKim, 1980) and was later consolidated as a problem-solving process applied to engineering and architecture (Cross, 2001; Simon, 1996). It has also been applied to ecologically sound design, starting with Papanek's (1985) work. It was later adapted as a basis

for innovative business practices (Brown, 2009; Kelley & Kelley, 2015) and taught as an educational methodology for creative and critical thinking (Faste et al., 1993; Seelig, 2015) at Stanford University. In recent years, it has also been used in the context of interdisciplinary and transdisciplinary research for sustainable development (Fischer, 2015; Pohl et al., 2020).

We propose that a design thinking approach in RWLs could help improve the design of interventions by matching them to meet the actual needs of the community. This is accomplished in several ways. First, design thinking can be defined as a human-centred approach to creative problem-solving (Brown, 2008; Brown & Katz, 2011; Brown & Wyatt, 2010). A core element to put humans at the centre of this process is empathy, where users' needs or, in our case, community members' needs, are first defined based on observations on the ground and through putting aside one's own assumptions (Brown & Katz, 2011). Identifying with the needs of a community through empathy allows designers to step outside of their own perspective and into the perspective of another, thus helping the designer to 'think outside the box'.

Second, iterative testing of ideas by rapid prototyping (Brown, 2008) ensures the inclusion of feedback during the entire development process (Mintrom & Luetjens, 2016). Design thinking aims to avoid presumed solutions by defining the problem together with stakeholders (Mintrom & Luetjens, 2016). This is accomplished by actively incorporating the feedback of stakeholders at the start of the design process, rather than at the end of a project when change is no longer possible. Thus, in the context of RWLs, design thinking can reduce the risk of researchers going into the field with a concrete solution already in mind, thereby neglecting the perspective of the community that the solution will affect.

Third, to know the stakeholders and their actual needs, they need to be observed in their daily lives and their natural environment *'where they live, work, and play'* (Brown & Katz, 2011, p. 382). Design thinking approaches emphasise the need to observe a variety of stakeholders who are affected by the problem rather than only the archetype of the 'average' citizen. Applied to the context of RWLs, understanding and engaging with stakeholders in their natural environment could include observational studies, conducting street surveys and participating in neighbourhood activities. Rather than relying on self-reporting, as is the case for traditional social science methods (i.e., interviews, surveys, multi-stakeholder workshops or focus groups), the stakeholders' perspectives are revealed in action in a naturalistic setting. This approach therefore merges an ethnographic approach with, for example, interviewing and surveying. Such an approach reduces the risks of self-selection bias (Agger & Lund, 2017; Lang et al., 2012), since observations are made within a geographic area or time frame rather than determined by the categories of people who are usually available and willing to volunteer for traditional activities of participatory research.

1.2 Designing evidence-based interventions

There is currently a lack of evidence regarding the effectiveness of interventions carried out in RWLs. Rather, contributions focusing on the conceptual aspects of RWLs dominate (cf. the special issue in GAIA and the books edited by Defila and Di Giulio (2018); Defila and Di Giulio (2019)). The discussion on how the substantive results of RWLs could be reported back to the scientific community is ongoing (Wanner et al., 2018). This is not surprising given the nascent state of RWLs. However, researchers involved in RWLs have the 'double aim' of fostering transformation while still producing scientific evidence (Bergmann et al., 2021). This evidence could include the degree of influence that interventions

have on a desired transformation. One often-described barrier to the integration of results from RWLs is the generalisability and transferability of the results. Due to the real-world situation of RWLs, contextuality often plays a crucial role, and it is very difficult to assess whether an observed change was the result of an intervention or the context in which the change occurred (Heiskanen et al., 2018).

We propose that one way to tackle this is by linking RWL research to existing scientific theories and empirical studies throughout the research process. This is important because in an RWL, as in transdisciplinary research, understanding the problem and the concerns of the community is the starting point (Hirsch Hadorn et al., 2006; Pohl & Hadorn, 2007), which is in contrast to a classical research project, where the current state of research would determine the design of an intervention. Thus, the interventions, while based on the needs of the communities, might not be directly supported by existing scientific evidence. Continuously consulting the scientific literature as a complementary strategy to a needs-based design might further improve the design of the interventions and their effectiveness. Furthermore, linking existing scientific theories and empirical evidence with interventions facilitates the testing of their effectiveness. Analysing whether the interventions are contributing to the expected changes and exploring the mechanisms behind these changes based on existing evidence may support researchers within RWLs to generate transformation knowledge. Likewise, continuous integration of current evidence supports learning across different cases, as the results of an intervention within one specific RWL can be discussed against the background of similar interventions elsewhere.

2 Data and methods–an illustrative example: transdisciplinary case study 2017

We use the 'Reallabor Hunzikerareal – nachhaltiges Verhalten fördern' in Zurich as a case study on how to design interventions within an RWL that are needs- and evidence-based. The Hunziker Areal is a multi-storied residential complex for more than 1000 inhabitants, with a socio-demographic profile similar to that of the Canton of Zurich (i.e., a representative group of people far beyond those already living sustainably). The Hunziker Areal is known for its energy-efficient construction techniques, as well as its mobility policy. Thus, the energy consumption and the associated CO_2 emissions of the inhabitants are drastically lower than those of the average Swiss household (Probst, 2014).

Between 2017 and 2020, a research project was carried out in close collaboration between researchers and the Hunziker Areal. Within this research, various initiatives and interventions to support more sustainable lifestyles were launched, promoted and scientifically accompanied. Initiatives and interventions were developed and implemented together with interested residents (e.g., members of neighbourhood groups) and the administration of the housing cooperative (Blumer et al., 2021).

This was the setting for the transdisciplinary case study (TdCS) in 2017, a project-based master's course of the environmental science master's programme at ETH Zurich that aims to work on societally relevant problems, connecting students, teachers and stakeholders (Stauffacher et al., 2006). The aim of this course is for students to learn how to define research questions around complex sustainability issues and to apply different transdisciplinary methods to collect data by taking on different case studies each year. They develop projects that aim to respond to both academic and societal needs. In 2017, the focus was

on sustainable food practices within the Hunziker Areal. The 14 students met on a weekly basis during the semester (14 weeks), followed by a three-week intensive block session.

Sustainable food practices are critical for mitigating climate change, as food production is responsible for about 35% of all greenhouse gas emissions (Xu et al., 2021). Dominant food practices, such as excessive consumption of meat and dairy or food waste, need to be challenged and transformed, requiring behavioural change from consumers (Garnett, 2011; Reisch et al., 2021). The aim of the course was to determine the existing food practices of the residents of Hunziker Areal to create interventions that would move these practices in a more sustainable direction and to test the effectiveness of these interventions. The students carried out the aim of the course in a three-stage process: (1) clarifying and focusing the topic, (2) designing the intervention and (3) implementing the intervention and testing its effects. Figure 1 illustrates this in more detail.

The first stage of the process of clarifying and focusing the topic consisted of conducting a literature review and gathering on-the-ground observations and information from initial interviews. For the literature review, the teaching team prepared a selection of relevant studies and grey literature related to sustainable food consumption, sustainable food practices and food waste, as well as methodologies to study these topics, such as behavioural interventions, field experiments and behavioural experiments. The students also identified additional literature based on the references of the studies and through individual literature searches. Concurrently, students visited the Hunziker Areal, at first guided by the coaches and local residents and then later on their own. They observed the local environment and tried to empathise with the perspective of the residents by, for example, joining the activities of the housing cooperative to experience how it felt to live in the RWL.

In the next stage of the process, the students started to design interventions. To do this, students combined these different data sources and on-the-ground experiences to identify specific insights into what challenges exist in relation to sustainable food practices for the Hunziker Areal residents. Insights were linked pieces of information that explained the

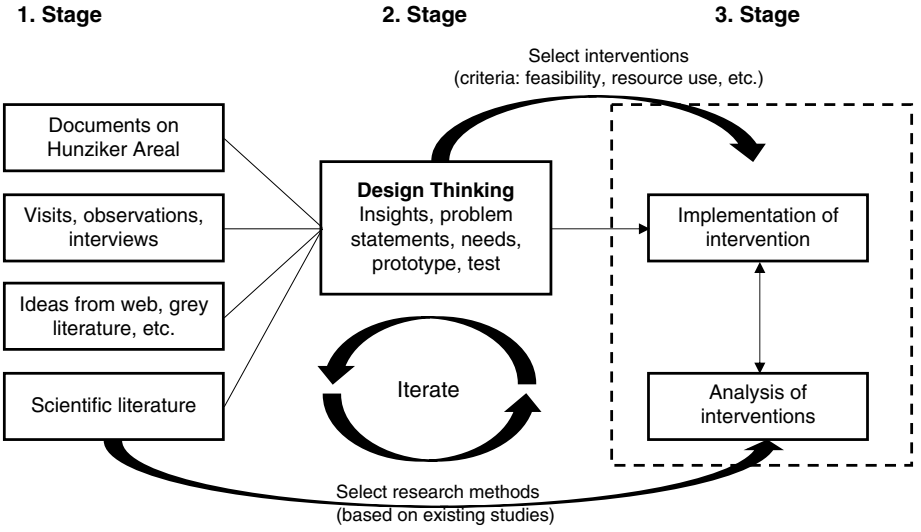

Fig. 1 Iterative integration of design thinking with scientific literature review: Research process of the TdCS 2017

'why' or 'how' of what was being observed, which were surprising to the students. All observations and discussions with inhabitants were written down in a shared file to allow for systematic analysis across the observations of all the students. Taking these insights into account, the students derived different problem statements, such as the lack of information on environmental issues of food production and the opportunities to access sustainable food in the Hunziker Areal. This process of identifying insights through observation, creating problem statements and identifying needs is drawn directly from the design thinking method. Based on the identified needs in the form of problem statements, prototypes of interventions were developed. After an internal feedback process for testing the prototypes, they were presented to a group of inhabitants from the Hunziker Areal. At this event, the inhabitants provided the students with feedback and rated the proposed interventions based on their perceived usefulness. The feedback and the results of the rating were then used to select four interventions and revise them according to the feedback received. Four interventions were chosen because they covered most of the identified needs and because it was possible for groups of three to six students to work on the implementation of each intervention.

In the last stage of the course, the students implemented the chosen interventions and analysed their effects. For each intervention, a group of students developed a research plan. This included going back to the scientific literature and formulating a concrete research question as well as the proposed method on how to test the effects of the intervention. The concrete implementation and data collection differed from group to group.

Overall, the students developed and implemented four interventions. We will use these interventions to explore whether the students were able to develop interventions that were needs-based and literature-related. We used the students' notes and reports of the development process, the intervention itself, as well as the results of the testing of the interventions.

3 Results and discussion

Based on the identified needs, the students developed 14 diverse prototypes of interventions, ranging from a smartphone application to cooking events. Along with the needs identified through the design thinking process, the students also went back to the scientific literature to refine their prototypes. The students derived their needs based on the insights they collected. Table 1 shows an exemplary selection of insights collected from one group of students. The insights collected show that knowledge is a crucial factor in determining one's food habits, be it knowledge about the possibilities in the Hunziker Areal (insight 1) or environmental knowledge (insights 2 and 3). However, there are other aspects at play, such as behavioural habits (insights 3 and 7), social norms (insight 6) and concern, stemming, for example, from the immediacy of the problem (insight 5). Taking these insights into account, the students derived a problem statement describing the lack of information on the environmental issues of food production, as well as the opportunities for sustainable food consumption on the Hunziker Areal. Furthermore, they determined a need for communication about the topic of food, which does not only focus on information transfer to the inhabitants but also on increasing concern and the propagation of social norms.

The students used the needs they derived based on the collected insights as a basis for brainstorming and the development of original interventions that address these needs.

Table 1 Exemplary insights collected by one group of students through observations of the Hunziker Areal

Insight No	Insight
1	Lack of information (e.g., about neighbouring groups) can lead to a lack of participation
2	Decision-making and sensible consumption is much easier when you have trustworthy, easily accessible information
3	Misconceptions about the link between food practices, food production and environmental impact lead to different priorities regarding concerns and actions to be taken
4	Not knowing the impact of their own behaviour (e.g., regarding food waste) and, to some extent, laziness makes it harder to address the food problem
5	Visible problems (e.g., amount of plastic from packaging) with an easy solution (plastic recycling) catch people's attention more easily than more abstract problems (e.g., CO_2 emissions from meat production)
6	Being aware of the negative aspects of (excessive) meat consumption is not enough to make people change their behaviour. There is also a social and cultural component to it
7	Some people see living sustainably as a considerable effort

Table 2 provides an overview of the four interventions, the target group they address and the needs that were addressed.

Later, each group used a variety of different academic concepts to further develop each intervention. These concepts ranged from social learning and information-based instruments to the role of media, such as movies, in triggering emotional reactions. Table 3 shows the main literature used either to develop the intervention or to test its effectiveness for transformation towards sustainability.

While all the groups returned to scientific literature when developing their interventions, for some groups this process even shaped the design of the intervention. The group that chose a participatory movie originally planned to produce a purely informative movie about the environmental effects of food consumption and the sustainable food initiatives present on the Hunziker Areal. This idea was developed through the design thinking process and triangulated with the relevant literature (Berg, 2011; Schrader & Thøgersen, 2011). When writing the research plan, the group further integrated literature on the potential of movies to reach its viewers emotionally and trigger social change (Finneran, 2014; Nash & Corner, 2016). Based on this literature, they integrated further elements into the movie, such as storytelling, where inhabitants of the Hunziker Areal talk about their personal strategies for eating more sustainably. They also integrated this element when designing the analysis of the intervention: they tested whether the movie reached its viewers emotionally in addition to testing the movie as a way of transmitting information and raising awareness of the consequences of current eating habits.

We observed a similar pattern for the group 'Children's Games', where literature was used in the first step to concretise the intervention. They identified children as an interesting target group and recycling as a need. The idea of using games was then derived from the literature on children's learning behaviour (Orellana et al., 2003). When looking at the development process of the 'Offal Degustation' intervention, we observe the interplay between needs-based and literature-related development of interventions nicely. Proceeding from the first literature research conducted at the beginning of the case study, the students were, based on the literature on the impact of meat consumption on greenhouse gas emissions, strongly invested in developing an intervention promoting a plant-based diet. However, the design thinking processes made them aware that this was actually not in line

Table 2 Overview of the needs identified and the goals of the four interventions

Main needs identified	Target group	Procedure	Strategy to foster transformation	Study effect of intervention
Compost experiment				
Closing the nutrient cycle for vegetable production in the local vegetable cooperative and for gardening activities in the Areal	Inhabitants, restaurants and gardening groups	Trial of organic waste collection at three different sites in the Hunziker Areal with written instructions on the accepted products	Provide composting facility and information about composting. Develop scenarios for future compost systems in the Hunziker Areal and assess their feasibility	Effect of different locations of the compost stations
Offal degustation				
Finding a more sustainable way of consuming meat, without compromising the taste and pleasure of consumption	Inhabitants who are not willing to fully replace meat but would like to reduce their meat consumption	Offal degustation event with the participation of inhabitants to include a culturally diverse offer and facilitate a multicultural exchange	Provide inhabitants with the experience of eating offal as well as recipes and further advice	Effect of confrontation with disgust
Children's games				
Solving visible problems related to food, such as plastic; making sustainability fun and social	Children of the Hunziker Areal	Workshop with playful activities for children around the issues of reusing and recycling resources	Raising children's awareness of plastic and correct recycling	Effect of games as educational tool
Participatory movie				
Communication of knowledge about the environmental impacts of food in a way that emotionally reaches people; inspiring them to engage in more sustainable practices	Inhabitants who are not informed about the environmental impact of food and the sustainable food initiatives in the RWL	Movie-making about the topic of sustainable food practices and about the existing solutions using a participatory approach, followed by a movie-viewing event	Inform inhabitants of the Hunziker Areal of the environmental impact of food consumption and the available initiatives facilitating sustainable food consumption	Effects of movies to trigger change through collective reflection and participatory movie-making

Table 3 Key scientific literature and concepts used for the development and assessment of the four interventions

Intervention	Key scientific literature included
Compost experiment	-Variation of behaviour depends on a person's needs (Birkenbeul et al., 2016) -Social learning or personal moral responsibility are increased by observing the behaviour of others (Brekke et al., 2010)
Offal degustation	-Cultural and social background in meat consumption (Gossard & York, 2003) -Promoting the 'community aspect' as a way of promoting behavioural change for more sustainable consumption (Moraes et al., 2012; Muniz & O'guinn, 2001; Szmigin et al., 2007)
Children's games	-Children's influence on their parents' consumption behaviour (Shoham & Dalakas, 2005, 2006; Ward & Wackman, 1972) -Active involvement of children facilitates the connection of new information with prior knowledge (Orellana et al., 2003)
Participatory movie	-Documentary films as tools to awaken empathy of audience and to trigger social change (Finneran, 2014; Nash & Corner, 2016) -Behavioural change may be facilitated by emotionally reaching people and by creating a feeling of community through social interactions (Nash & Corner, 2016)

with the needs of the inhabitants, which was to make meat consumption more sustainable. This led them to the idea of promoting offal as a more sustainable way of consuming meat compared to fine cuts. For the design of the intervention, the group again integrated scientific literature. They chose a degustation event to provide inhabitants with the experience of eating offal, as community aspects have proven to be pivotal in triggering more sustainable eating habits (Moraes et al., 2012; Muniz & O'guinn, 2001; Szmigin et al., 2007).

The compost intervention was developed according to a very well-defined need to close the nutrient circle and the intervention to introduce a compost system. This intervention was co-developed with the vegetable cooperative that is providing the RWL with vegetables and was itself not strongly based on the literature. However, when planning the analysis of the intervention, the group chose to install different compost sites and verify whether the location of the compost best fit the needs of the inhabitants (Birkenbeul et al., 2016; Brekke et al., 2010).

After developing the scientific basis of the intervention, the students tested whether the refined intervention fit the identified needs by presenting prototypes of the interventions to receive feedback from the inhabitants. Thereby, the students were able to develop interventions that were shaped through and accepted by the inhabitants. The students then tested the expected effects of each intervention.

Table 4 shows which methods the students used to test the effects of the interventions, as well as the results. The results show that each group was able to at least partially tackle the identified needs of the inhabitants. They provided ideas for more sustainable meat consumption, scenarios for different compositing solutions. Further, they increased the awareness of and knowledge about recycling and the environmental impacts of food. Additionally, each group collected valuable data on the mechanisms behind the interventions. The 'Compost Experiment', for example, showed that the location of the composting station is key for the quality and quantity of the compost. This is in line with what Birkenbeul et al. (2016) found on the relation between people's needs and their behaviour. The 'Offal Degustation' group found that their intervention led to a significant increase in the share of participants who stated they liked offal but displayed no significant change in their level of

Table 4 Overview of methods used to evaluate interventions and results

Methods	Results
Compost experiment	
-Analysis of compost quality and quantity at three different sites -Interviews with inhabitants and restaurant owners	-Development of three scenarios for possible composting solutions -Location of the compost sites has a major influence on the quality and quantity of the compost as well as on acceptance of the project
Offal degustation	
-Survey of degustation participants -Interviews, Participant observation	-Degustation led to a significant increase in participants that indicated a liking of offal but no significant change in the level of disgust -The willingness to prepare offal slightly increased after degustation
Children's games	
-Participant observation	-The games attracted many children and their parents from diverse social backgrounds. The participants enjoyed the games -Informal environmental learning experiences are an effective tool for increasing children´s environmental knowledge and awareness
Participatory movie	
-Survey with participants before and after movie viewing, Interviews with inhabitants who participated in the movie	-The movie increased knowledge and concern about the impacts of food -Increased willingness to join a sustainable food cooperative in the Areal -Including inhabitants of the Areal in the movie led to discussions on sustainable food habits and made the movie more emotionally involved for viewers

disgust, which shows that the intervention in the form of a one-time degustation event was probably not sufficient for changing deep-rooted feelings like disgust.

The outcome of the process was that the students were able to address the needs of a broad diversity of inhabitants. Already during the early phases, the students were sensitised to the effects of participation bias and were advised to find strategies to reach inhabitants that were not part of the 'usual suspects'. By examining internal documentation where the students systematically made notes of their observations, we observe the following: First, the largest share of observations conducted on the Hunziker Areal was in the form of an open street survey. Students walked around or attended events and started conversations with whomever they met. Students tried to participate in events that were not related to food to ensure that not only those already interested in the topic were addressed. Second, the students tried to vary the time points of the observations by being present on the Hunziker Areal during the day, but also in the evenings and at weekends. Third, the structure of the interventions showed that students were able to reduce participation bias. The 'Offal Degustation' group specifically chose a multicultural approach and invited people from the Hunziker Areal to share traditional offal recipes from different cultures. In the end, two inhabitants, one from Eritrea and one from Mexico, supported the group during offal testing. The group that was developing and testing the recycling game chose children, who, according to Brown and Katz (2011) are *'extreme users'* (p.382), as the target group. Furthermore, the cultural backgrounds of the children participating in the recycling

games were very diverse. While the students were certainly not able to avoid selection bias completely, applying the tools and principles of design thinking allowed a wide variety of inhabitants to be included in the development or implementation of the interventions.

Overall, these observations show that the students iteratively integrated design thinking methodologies and the use of scientific literature. They managed to develop interventions that were based on the needs of a variety of inhabitants or the RWL. These interventions were, in turn, certainly inspired by their initial reading of scientific literature (e.g., on field/behavioural experiments). The scientific literature also enabled them to systematically test the effects of these interventions. The analysis of the effects shows that all four managed to fulfil the desired effects, at least to a certain degree. The introduction of scientific literature helped shape the final interventions as well as the analysis of the interventions. We show how the data collected during the implementation and analysis processes of the interventions already fit with the related scientific literature. We assume that this facilitates the communication of the results for a scientific audience.

4 Discussion and conclusion

RWLs are pivotal in combining research and action for sustainable development (Parodi et al., 2016). In this article, we focused on a project-based master's course on sustainable food practices in the RWL "Reallabor Hunzikerareal – nachhaltiges Verhalten fördern" in Zurich. First, we showed that design thinking (Brown, 2008; Brown & Katz, 2011; Brown & Wyatt, 2010) can help to develop interventions that are based on the needs of the inhabitants. Second, we showed how iterative integration with scientific literature in the research process helps refine the final intervention and test its effectiveness and the mechanisms behind it. Furthermore, it facilitates the communication of substantive results gained from evaluating the effectiveness of interventions for a scientific audience, thus responding to the burning needs of the RWL community (Wanner et al., 2018).

We found that students were able to develop four distinctive and varied interventions for transforming sustainable food practices using design thinking. Design thinking supported the students in keeping an open mind to the actual needs of the inhabitants and thus avoided their own assumptions guiding the problem definition (Fischer, 2015). Students demonstrated 'outside the box' thinking. Through street surveys and attending events and meetings on the Hunziker Areal, students were able to gather observations of a diverse group of people. While participation bias, common in such projects (Agger & Lund, 2017; Lang et al., 2012), was not fully avoided, using strategies from design thinking helped to reduce it. By designing and presenting prototypes of the interventions, the students enabled the inhabitants to contribute to the selection and final design of the interventions.

Moreover, we found that all the interventions were based on specific scientific concepts and literature, such as the role of the community in fostering behavioural change. By exposing students from the beginning, and concurrently with their observations and interactions with local people, to a broad range of relevant scientific literature, ideas for possible interventions emerged from both sources. It is interesting to note that the four groups balanced the input of scientific literature and local exposure differently: while the compost group seemed most inspired by local needs, the participatory movie was inspired largely by the respective scientific literature. All groups used scientific literature to refine the first ideas for interventions developed through the design thinking process and to ensure that the proposed effects of the interventions were testable. We argue that by integrating

scientific literature throughout the process and iteratively, results from the interventions, despite being highly context specific (Heiskanen et al., 2018; Wanner et al., 2018), can be compared with and contribute to the current state of research.

Combining our two observations, we contend that to develop needs-based interventions that produce results relevant to science, researchers in RWLs need to keep a very open mind to avoid bias and to identify important needs in conjunction with reviewing the relevant scientific literature. This is, of course, challenging: relating to relevant literature too early in the process might leave researchers with concrete ideas about potential interventions or research questions they would like to study, thus reducing openness to the actual needs of the inhabitants. This is also supported by Bergmann et al. (2021) who find that researchers involved in RWLs find it difficult to balance the societal and research aims within RWLs. They also find that researchers tend to focus more strongly on the societal aims of the RWLs. While this focus on societal aims is of course highly important to design interventions that are needs-based, it may make reintegration of the evidence gained more difficult. Only drawing on the relevant literature once the interventions have been implemented and tested may make it harder to relate the collected data to the current state of research.

As we studied only one concrete example of a project-based master's course within an RWL, this article faces some limitations. We used a teaching course where the research was conducted by students, and therefore, we cannot be sure whether the observed effects would also occur in research conducted by junior and senior scientists. Students are, compared to researchers, less exposed to pressures in academia, such as the 'publish or perish' mentality or competition about grants (Waaijer et al., 2018). Additionally, experiences from similar teaching formats show that students might contribute observations and innovative ideas that more senior researchers would not consider (Krütli et al., 2018). However, students obviously have less experience in scientific work, which might make the integration of scientific literature more difficult. Nevertheless, we assume that the results of this study might be beneficial for other researchers involved in RWLs. We show that planning for the iterative integration of scientific research is not only important to test the effectiveness of the interventions and to facilitate re-integration of the collected data; it might also shape and improve the design of the interventions in the first place. We invite other RWLs to share their approaches and experiences while designing interventions. We are convinced that the RWL community needs to improve its methodologies to meet the double challenge of achieving impact in the real world and producing novel scientific knowledge for academia.

Acknowledgements We would like to thank all students of the tdCS 2017 for their diverse and valuable contributions as well as the administration of the housing cooperative and all residents of the Hunzikerareal for their great support and commitment.

Funding Open access funding provided by Swiss Federal Institute of Technology Zurich.

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