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Collaborative learning for fostering change in complex social-ecological systems: a transdisciplinary perspective on food and farming systems

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This paper aims to conceptualize collaborative learning methodologies used in transdisciplinary research projects dealing with change in complex situations, such as farming and food systems of developing countries. For this purpose we propose a framework for understanding collaborative learning approaches based on theoretical considerations and 18 selected case studies. The cases were assessed that have a clear focus on collaborative learning in the context of farming and food systems of developing countries. We suggest that a 'collaborative learning' process includes four steps: (A) *establishing cooperation*, (B) *dialogue,* (C) *discovery,* and (D) *application of new knowledge*. The necessity of making the process of actor identification more explicit is highlighted. Furthermore, many projects did not fully conceptualize application of knowledge as part of the research. Trust among the participants was a key to promoting knowledge exchange and mature reflection, and results from a carefully designed and facilitated process. If this was the case, participants perceived that they gained something meaningful, such as new relationships, or new knowledge and skills. Awareness of their role in the process of change was strengthened.

Keywords: collaborative learning; knowledge integration; change process; transdisciplinary research; capacity building; food systems; farming systems; developing countries

Food and farming systems can be considered as complex social-ecological systems consisting of human, technical and natural components, all contributing to production and value addition processes. As they form part of the ecosystems of specific locations, they are diverse and heterogeneous over space and time. Furthermore, they are characterized as dynamic systems with many linear but also non-linear interrelations between different components (Folke et al. 2002). As some of the interrelations are circular, the systems respond to events via feedback mechanisms that either stabilise or amplify and reinforce processes within the system. All this tends to make their outcome uncertain and unpredictable.

Food and farming systems deeply depend on human management, and as human activity systems, they are established, shaped and maintained through the farmers' management practices (Norman 2000, Fairweather 2010). These practices are based on the human actors' values and strategic goals, and their understanding of how these actions can influence the system and its outcomes (Kaufmann et al. 2013). In food and farming systems, there are multiple actors involved each with different interests, perceptions, access to information, and types of knowledge and they mutually depend on each other's actions.

Globally, main problems in farming and food systems include, but are not limited to: food insecurity; degradation and scarcity of natural resources such as water, soil and biodiversity; climate variability and change with its associated extreme weather and disruption of expected patterns; market uncertainty and instability; and health hazards and food contamination. These problematic situations in social-ecological systems cannot be solved by dealing with the ecological or technical components alone. Thus, fostering change in complex systems requires more than technological solutions where 'real world' actors are seen as passive recipients of information and new or improved technologies. This is evinced by the failure to translate strategies for improvement or new technologies from formal research to the real world (van Veldhuizen et al. 1997, Critchley and Nyagah 2000, Leeuwis 2004). Hence, research that aims at fostering change in complex systems needs to involve real world actors. This also recognises that in human activity systems, change can only happen if relevant actors change their actions. If the changes needed are beyond the scale of individual control, collective or coordinated actions of multiple actors are required.

Humans might change their actions because of external motivation, such as incentives or new regulations, or because of internal motivation, arising from better understanding gained from a learning process. As stated by Checkland (1981), whoever owns a problem should be a co-owner of the process to solve it.

Collaborative learning involving multiple actors could thus be a promising approach to solving problems and fostering change in complex social-ecological systems Even though learning among interconnected actors, sometimes also referred to as stakeholders, is recognized as a key element to resolve problematic situations collectively faced (Leeuwis and Pyburn 2002), little is known about how to enhance learning that promotes change in relation to sustainability issues (Tschakert and Dietrich 2010). To improve approaches that encourage learning processes among multiple actors who share a common problem, Lang et al. (2012) and Cundill et al. (2014) specifically encourage comparative analysis of learning approaches in different contexts.

In this paper, we thus aim to develop a framework for understanding and conceptualizing collaborative learning approaches that facilitate change in complex social-ecological systems based on theoretical considerations and a reflection of experiences shared recently by other authors. We compiled the methods used in 18 transdisciplinary research projects and identified their purposes and outcomes. In doing so we made the connection between learning theories behind the concept of collaborative learning and methods used in the respective research projects explicit. This serves at supporting other researchers in choosing approaches and methods when they aim at embarking on transdisciplinary research. The case studies were undertaken in Africa (Ethiopia, Ghana, Kenya, Morocco, Senegal, Tanzania, and Zimbabwe), Latin America (Argentina) and Asia (Benin, Nepal, and Vietnam).

Methodological approach

We start by reviewing relevant theories on 'collaboration' and 'learning' (including Vygotsky 1978, Kolb 1984, Engeström 1987, Nonaka and Takeuchi 1995, Mezirow 2000). We then present a framework for understanding 'collaborative learning', based on which we assess 18 recently published cases where collaborative learning was applied for fostering change in farming and food systems of developing countries (see Table 1).

Although each of them has different perspectives and varied objectives, all focus on learning processes involving different actors. A content analysis of the information provided was done to assess criteria that relate to the framework presented below. We further compile the strengths and weaknesses as given by the authors when reflecting on their methodology. Selected articles were coded using computer-assisted Qualitative Data Analysis software in family R (Huang 2012). We used the coding to construct tables for further synthesis.

Table 1. Selected articles using a collaborative learning approach

1	Chaudhury et al. 2013 'Participatory scenarios as a tool to link science and policy on food security under climate change in East Africa'
2	Cinderby et al. 2011 'Participatory geographic information systems for agricultural water management scenario development: a Tanzanian case study'
3	Faysse et al. 2012 'Local farmers' organisations: a space for peer-to-peer learning? The case of milk collection cooperatives in Morocco'
4	Halbrendt et al. 2014 'Differences in farmer and expert beliefs and the perceived impacts of conservation agriculture' [Nepal]
5	Jones et al. 2014 'Assessing participatory processes and outcomes in agricultural research for development from participants' perspectives' [West Africa]
6	Kiptot and Franzel 2014 'Voluntarism as an investment in human, social and financial capital: evidence from a farmer-to-farmer extension program in Kenya'
7	Krupnik et al. 2012 'Improving irrigated rice production in the Senegal River Valley through experiential learning and innovation' [Senegal]
8	Lukuyu et al. 2012 'Disseminating Improved Practices: Are Volunteer Farmer Trainers Effective?' [Kenya]
9	Mapfumo et al. 2013 'Participatory action research (PAR) as an entry point for supporting climate change adaptation by smallholder farmers in Africa' [Ghana and Zimbabwe]
10	Nicetic and van de Fliert 2014 'Changing institutional culture: participatory monitoring and evaluation in transdisciplinary research for development, Vietnam'
11	Podestá et al. 2013 'Interdisciplinary production of knowledge with participation of stakeholders: a case study of a collaborative project on climate variability, human decisions and agricultural ecosystems in the Argentine Pampas'
12	Sanginga et al. 2010 'Tracking outcomes of social capital and institutional innovations in natural resources management: methodological issues and empirical evidence from participatory bylaw reform in Uganda'
13	Sangole et al . 2014 'Community based participatory monitoring and evaluation: impacts on farmer organization functioning, social capital and accountability'[Kenya]
14	Schiffer and Hauck 2010 'Net-Map: collecting social network data and facilitating network learning through participatory influence network mapping'[Ghana]
16	Spielman et al. 2011 'Rural innovation systems and networks: findings from a study of Ethiopian smallholders'
17	Totin et al. 2013 'Mulching upland rice for efficient water management: a collaborative approach in Benin'
18	Zossou et al. 2009 'The power of video to trigger innovation: rice processing in central Benin'

Results

A framework for understanding collaborative learning

Collaboration is defined as a process through which parties who see different aspects of a problematic situation can constructively explore their differences and search for solutions that go beyond their own limited vision of what is possible (Grey 1989). By collaborating, exchanging and combining knowledge and experiences, it is expected

that different actors together are more likely to achieve relevant outcomes than each of them alone. Nevertheless, it is possible that not all of the actors agree or share a common goal. Rather, to be a productive interaction, all of those involved must be willing to engage in a process which might be specifically designed to accommodate diverse viewpoints and perspectives – some of which may be at odds with each other and appear irreconcilable.

The benefit of collaboration is that important aspects of the issue, which might have otherwise been unconsidered, can emerge through the process of soliciting a wide range of perspectives (Cuppen 2012, Roloff 2008). Likewise, this increases the probability that a research project, governance strategy etc. is effective, relevant and can be implemented. For example, different actors' experiences will lead each of them to know certain parts of a process which might not be known by others. Depending on their influence, some actors may have the ability to promote or discourage implementation of a project or idea within different groups, institutions, or regions.

Learning follows the principle of continuously reducing information or increasing order in the information either by structuring it or recognizing patterns (von Cube 1967:53). How learning is achieved when aiming to foster self-driven change in social-ecological systems is explained by relevant adult learning theories: experiential learning, transformative learning and expansive learning with its origins in socio-cultural theory. The first two learning theories focus on a change in behaviour and cognition. The third learning theory is based on the assumption that we learn through our interactions and communication with others, and as a result there is not only a change in behaviour and cognition, but also a change in the activity system the learners belong to.

Experiential learning theory characterizes learning as a process of creating knowledge through transformation of experiences, or learning-by-doing. Kolb (1984:38) defines experiential learning as 'the process whereby knowledge is created through transformation of experiences'. It follows an iterative learning cycle composed of four stages: concrete experiences, reflective observation, abstract conceptualization, and active experimentation (Kolb 1984). The concrete experience forms the basis for observation and reflection; with the experience one has the opportunity to consider what is working or failing (reflective observation), and to think about ways to improve on the next attempt (abstract conceptualization).

Since practitioner knowledge is usually derived from experience and partially implicit, reflection of their own actions can help to make this knowledge explicit and to share it with other participants. Explicit knowledge can again become implicit if it

becomes incorporated into new procedures and 'ways of doing'. Facilitating this process of dynamic transformation of knowledge has been described by Nonaka and Takeuchi (1995) as an important aspect of learning and as a source of innovation. Their knowledge spiral model includes four stages known as **s**ocialization, **e**xternalization, **c**ombination and **i**nternalization (SECI). This process can be actively promoted, for example by creating spaces for interaction that help overcome hierarchical structures and facilitate mobility, e.g. people moving between different departments of a company or project.

Another more recent learning theory is the transformative learning theory. Mezirow (1991, 2000) describes learning as a reflective process that enables an individual's perceptions to be altered. It centres on how to encourage learning so that an individual's relevance system is transformed through critical reflection. The relevance system is that internal structure that influences which information a person becomes aware of and internalizes. A change in the relevance system occurs after an individual faces a problem where past experiences offer no immediate solutions, also called *disorienting dilemma*. According to Mezirow (2000), there are two ways by which individuals learn: instrumental and communicative. Instrumental learning refers to improving a task-oriented problem, while communicative learning is related to the understanding of the meaning of what is communicated. A change in the relevance system is often leading to changes of the meaning of the issues observed and communicated as a new understanding is gained.

It was Lev Vygotsky who first stated that we learn through our interactions and communications with others. His notion of zones of proximal development (ZPD) has implications for collaborative approaches. According to Vygotsky, the ZPD is the distance between the actual and potential learning of an individual, where the actual is determined by his or her independent problem-solving capacity, and the potential is determined by the individual's problem-solving capacity under guidance or in collaboration with peers (Vygotsky 1978:86). Hence, collaboration with others enables interacting in this way to go beyond their current learning capacity.

The expansive learning theory states that using contradictions, learners are involved in constructing and implementing a new concept (and object) of their activity (Engeström 1987). It explains how a group of people transforms an activity. Here, learning is not only manifested in a change of the individuals' behaviour and cognition, but also in a change of actions finally leading to a new socially accepted practice.

Based on these theoretical considerations, we propose that a collaborative learning approach could be conceptualized as a set of four phases (Figure 1). The first phase, (A) *establishing the collaboration*, is an important precondition for all subsequent activities and influences their outcomes. It entails identifying relevant actors, institutionalizing the partnership, and agreeing on shared goals and the approach among the participants. Institutionalizing the partnership usually means forming one or several groups with defined membership and rules of operation. Official registration as a legal entity may be found necessary to acquire or share funds, facilitate continuation of activities beyond the project life and manage intellectual property rights.

During the process of *dialogue* (B), information from different actors with different types of knowledge, experience, perspectives, and hence relevance systems, can be communicated, integrated, acknowledged, and synthesized. By questioning, clarifying contradictions and debating, a broader and deeper understanding is achieved.

The process of *discovery* (C) is intended to actively fill knowledge gaps and build capacities. It may include, for example, conducting trials and other forms of practical experiments, e.g. building prototypes, 'pilot' activities, such as new processes or organizational structures. By evaluating what works and what does not, and by drawing conclusions regarding what might need to be done differently, the participants identify practices that help to resolve the problematic situations in an iterative process.

Applying the new knowledge (D) is the basis leading to individual or collective actions where the new practices are consolidated into a more broadly recognized social activity.

Several learning cycles may be required. To enhance learning from and about the collaborative learning approach itself the whole process should be documented.

Applying the collaborative learning framework to documented experience

Following the above mentioned framework, we assess cases shared by other authors by looking specifically into the ways how actors were identified and how their interaction was established; we further assess the collaborative learning process itself; and lastly the outcomes of the process in view of the 'real world' problem that was addressed. The first aspect thus deals with building the collaborative team. The second aspect is related to the collaborative learning process itself, and particularly how knowledge is integrated, created and applied. The third aspect reflects the outcomes from the collaborative learning process in view of the problem addressed. A

table summarizing the respective purpose and outcomes for the methods used is given at the end of each section.

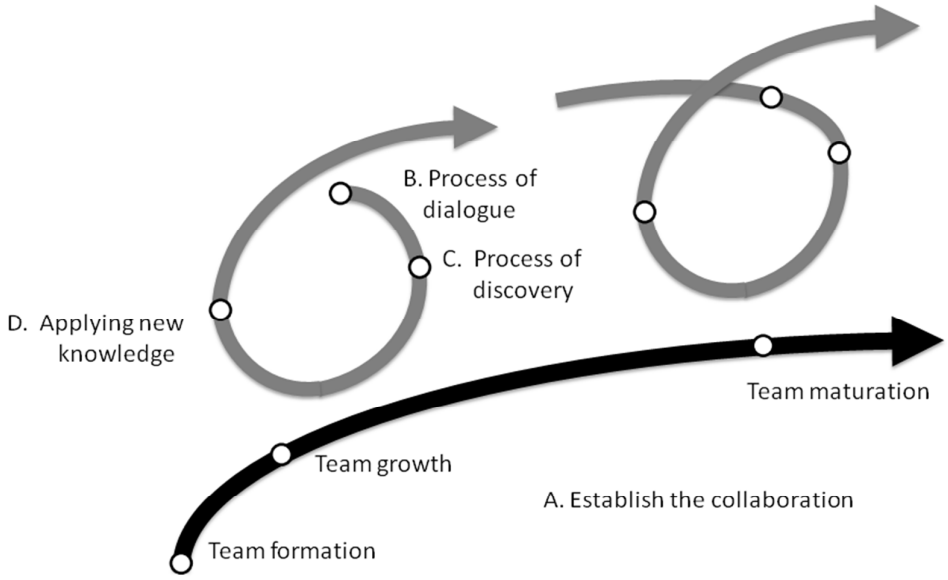

Figure 1. Four phases (A-D) of the collaborative learning approach and associated process of team development.

Methods for identifying actors and establishing a system of collaboration
The majority of articles analysed state that active involvement of different actors is one of the bases for success. Their identification and representation was achieved using different methods such as network analysis, iterative stakeholder analysis, concept maps, net-maps, interviews, and by establishing regular communication (Table 2).

Social network analysis is specifically recommended by Spielmann (2011:195) for researchers seeking to identify and implement relevant innovations. Although some participants might be selected for participation due to certain criteria such as interest in a particular issue, it can be useful to approach actor analysis iteratively throughout a project period as knowledge of the issues might change (Jepson and Eskerod 2009, Reed 2009). Podesta et al. (2013) highlight the importance of paying attention to team compositions, to achieve real interactions and synergies. Key for enhancing participation in most of the projects is an agreement on the goals and approach, as well as a clarification of the role of each of the participants in the process (Table 3). In some cases, farmers self-organized into groups to address specific issues (e.g.

Mapfumo et al. 2013.), or participants were invited by researchers and peers (e.g. Krupnik et. al. 2012).

Table 2. Methods to identify participants and establish a system of collaboration

Goal	Method applied	Purpose	Outcome
Representation of diverse actors	Network analysis (3,15) Net-Map (14) Stakeholder analysis (17) Interviews (9)	Identify institutions and actors (9,11,14) Uncover power relations and sources of conflict (14) Insight into participant's background and wishes (14,15,17) Knowledge flows (14,15)	Multiple types of actors included Diversity of interests represented
Actors' participation and roles	Participants selected by: research team (2,4,5,10), peers (6) and invited to participate as volunteers (7,8,16)	Establish selection criteria for participation (4,5,10), e.g. willingness to learn, good communicators, honest, committed, skills such as record keeping	Team formed
	Individual communication (7) General meeting (2,10,16)	Definition of a common agenda that includes objectives, structure of the approach, roles and responsibilities (16,17)	Clear benefits, roles and responsibilities
	Communication platform (7,10)	Regular meetings (face to face or via video conference)	Communication established
	Process supported by (professional) facilitators (1,2,8,10)	Giving all participants the opportunity to express themselves and valuing the participation (2,5,10,11)	Power differences balanced

The numbers in brackets refer to the research project from which the example is drawn (see Table 1).

Main challenges were departure of key staff and participant drop-off. Losing actors resulted in a loss of momentum. The main cause of participant drop-off was research fatigue. Research projects avoided research fatigue by addressing actors not usually involved in other projects in the area (e.g. such as NGO contact persons), by monitoring project progress, maintaining relationships and enhancing communication. Giving all participants the opportunity to express themselves and valuing their participation was also seen as key in enhancing participation and avoiding research fatigue. Experienced facilitators used methods to help mitigate power imbalances during group meetings and discussions.

Methodologies used for the collaborative learning process

A process of dialogue, discovery and in some cases application of new knowledge was assessed in the cases we reviewed. A commonality was the use of visual tools and

methods to have a visual representation of a system, its interactions, problems and contradictions. Visual representations enhance mature discussion and reflection among different actors. For instance, to bring together multiple perspectives and come to a common problem understanding, Halbrendt et al. 2014 used cognitive maps integrated with scenario building and on-farm experimental plots; to analyse information during the process of knowledge creation, Cinderby et al. 2011 used participatory mapping to identify mutually accepted solutions to environmental and water management; and to visualize knowledge, networks, goals, sources of conflict, and potentials for cooperation Schiffer and Hauck (2010) used Net-Map (Table 4).

Sharing practitioners' strategies and objectives helped to broaden insights into their priorities and was instrumental to achieve a common problem perception or joint problem definition. Creating knowledge through a process of discovery was characterized by iterative activities in which actors compared practices or management strategies, collectively, shared information (with or without conducting experiments or trials) analysed it and interpreted it.

A further commonality identified was the collective assessment and evaluation of one's own and others' ideas, practices or innovations. Ample time was allocated for these discussions allowing for intensive exchange and debate. The collaborative learning process in several research projects ended here; hence participants had not yet applied the new knowledge, or this was not documented. Some cases proceed with the application of new knowledge in the form of collective or individual actions to scale up, e.g. using farmer-to-farmer exchange methods such as the screening of participatory video (Zossou et al. 2009) and farmer-to-farmer extension (Kiptot and Franzel 2013, Lukuyu et al. 2012).

Because of the often rigid structure of research project funding, Podestá et al. (2013) reported common challenges for the collaborative learning process. The first difficulty was to create a joint problem definition, where researchers and practitioners together decided upon the need to organize the process, and how to ensure that a project's goals, tasks and activities depart from a common reference point. Some project leaders overcame this concern by framing the project according to previously known concerns of actors, or by including steps during the initial phase of the project that were specifically geared towards creating a common understanding of the problem or, in cases of controversy, by clearly representing multiple perspectives, options and possibilities for understanding a problem.

In some cases, researchers emphasize the importance of promoting an iterative process for joint understanding of problems and results, as the research process and

methods are influenced by participants (Mapfumo et al. 2013). Other difficulties identified were to achieve that diverse actors agree upon a common agenda, and to integrate needed flexibility in the project framework for responding adequately to feedback from participants.

Outcomes from the collaborative learning process

Outcomes from the collaborative learning approaches are empowering, as they enhance actors´ long term capacities. These outcomes were found to be related to (1) agency, and/or (2) improved action possibilities. Agency entails the strengthening of social capital[1] by enhancing trust, reinforcing networks, and increasing collaboration. Furthermore, it helps strengthening human capital mostly in the form of capacity building. Outcomes related to increased action possibilities, include a change in the relevance system of actors, and enhanced problem-solving capacity.

Not all outcomes, such as trust or strengthened networks, can be directly measured and so must be assessed through the use of proxies (Table 4). A prevailing success factor reported was that trust among actors promoted knowledge exchange and mature reflections. Furthermore, collaborative learning was reported to strengthen vertical and horizontal networks and enhance the ability of multiple actors to address a common problem. For example, programs which aim to strengthen networks and capacity for rural development in multiple countries are discussed by Chaudhury et al. (2013). Capacity building was evinced by increased organizational management capacities of participants, and improvements made to the collaborative learning process after feedback. Some cases demonstrate institutionalization processes linked to supporting collaborative learning.

Reported outcomes with regard to resolving the problematic situation in the real world are increasing action possibilities via: (1) a change in the relevance system, or (2) enhanced problem-solving capacity. A change in the relevance systems among researchers, practitioners and other actors occurred through joint efforts to consolidate a common understanding of the problem which also integrated representations of diverse and sometimes contradictory understandings, as well as processes to find solutions and to develop innovations or improvement options. For instance, Nicetic and van de Fliert (2014) co-develop new soil management practices that respond to important parameters defined by farmers, such as labour requirements.

Table 3. Methods for dialogue, discovery and application of new knowledge

Collaborative learning phases	Method	Purpose	Outcome
Process of *dialogue:* Integrating knowledge	Literature review (9) Interviews (9,17) and narratives (2)	Identify criteria farmers use to assess the success of their systems or the challenges faced in their systems (16)	Diverse inputs or knowledge types
		Identify past and present farming practices, farmers strategies and objectives (2,9,10,17)	Multiple perspectives on the complex problematic situation
	Collective meetings with multiple actors (3,9,7,10,16), focus group discussions (7), workshops (1,7) Communication tools, e.g. problem trees (9,13), visual assessment (13,14) Field days/visits (10) Participatory mapping (2), Cognitive maps (4), Net-Map (14)	Identify relations in different perceptions, competing interest or problems (4,16) Broader insight into local priorities (4,7,10,14,16) Mapping main livelihood management strategies (2)	Perspectives exchanged and modified
		Shared problem perception (1,4,7,9,10,13,14), and directions for sustainable solutions (1,2,4,7,13,14,16) Identify perceived sources of vulnerability (2,7) Identify relevant innovation (3,15) or solutions to test (7,16)	Shared understanding develops
Process of *discovery:* Constructing knowledge	Co-inquiry (5), participatory trial development (7,9,16) Modelling and (on-farm) simulation (1,2)	Testing of new/improved strategies in production systems (7,10,16) Co-construction, simulation and evaluation of scenarios/models with real actors in real farms/situations (1,2)	Experience gained from testing new ideas
	Monitoring farming practices / strategies (7,10,16)	Meeting with different actors to monitor progress (7,10,16)	Systematic information
	Group discussions (7,10) Co-opting (16) Participatory assessment of farming practices (7,10,16)	Discussion of experiments/innovations (7,10) Comparing practices and management strategies between farmers (7)	Information analysed and cause-effect relations revealed
	(Co-)construction of scenarios (1,2,4) Participatory evaluation (10,13,16) Co-developing options for improvement (7) Role play (9,13)	Participatory assessment and evaluation of own and others' practices, innovations or ideas (7,10,13) Unfold pathways to achieve desired visions (2,14) Recommendations for next season's experiments (7,10,13) Prioritized fields of action (9)	Results interpreted and conclusions drawn
Applying new knowledge	Participatory action planning (9), Large scale test (10), Implementation of changes (9) Farmer-to-Farmer (video based) exchange (3,6,8,16,17) Field trips (16)	Test promising systems in larger areas (10) Spread and scale up the innovative practices (6,8,16)	Change of practice, shared actions, new action options and activities

The numbers in brackets refer to the research project from which the example is drawn (see Table 1).

In many of these transdisciplinary research projects, the process enhanced the problem-solving capacity of participants, including researchers, as when participants gain a better understanding of the complexity of the systems analysed, and their capacity to assess relevant contextual information is augmented. Enhancing the problem-solving capacity of participants supported innovations that fit in the respective local contexts, as participants actively looked for solutions, implemented them and monitor the outcomes (Table 4). For instance, Totin et al (2013) reports how different mulch alternatives where tested to come to a common agreement on the best option.

Increased action possibilities were reported mostly in the form of improved practices, strategies and tools adapted to 'real world' actors' realities (Krupnik et al. 2012, and Nicetic and van de Fliert 2014). Other outcomes reported were the co-creation of communication material, and recommendations for extension programs and policy makers (Table 4).

One difficulty found in these examples was that participants, including researchers, worried about achieving particular results (e.g. publications in scientific papers, new methodologies), which occur at different time frames. Some researchers found increased motivation from the satisfaction of seeing some of the results immediately put into action.

Discussion

The proposed framework takes up and integrates earlier work on collaborative learning, knowledge creation and innovation. Figure 2 shows demonstrates how the three phases that follow the identification of actors and establishment of collaboration (*dialogue, discovery, application*) correspond with the knowledge spiral model of Nonaka and Takeuchi (1995). These authors do not consider actor identification separately because their model refers to people working in one company, whereas in transdisciplinary research projects, actors usually have to be identified and the collaboration system has to be newly established for the project life or beyond. In all the reviewed examples, 'real world' actors with diverse interests, perspectives, access to information and knowledge types were involved in order to foster debate and knowledge exchange. However, in many cases, details on how actors were identified were not provided. How the collaboration among them was established varied among different projects. Some were established by a local initiative, while in most cases participants were invited by the researchers, either to speak for themselves, or to represent a group with assumed similar interest and perspectives (see Table 2).

Table 4. Learning outcomes from the collaborative learning process

Learning level	Outcome	Example
Agency	Social capital: (i) enhanced trust	Recognition of others' perspectives and goals, and clarifying roles (1,11), as actors feel valued Establishing long term relations (6,8) Cohesive team (11,13) Mutual understanding (1,4,5)
	(ii) strengthening networks	Horizontal networks in between farmers e.g. through (in)formal exchange (5,6,8,13,15,17), and visits (6,8,16), workshops (1) Vertical networks between different actor in the project (1,5,6,12), e.g. through a communication platform (9,16)
	(iii) enhanced collaboration	Between researchers and farmers in the experimentation (4,7,9,16), innovation process (5,7), building models/scenarios (1,2) Among farmers in the collaboration process (3,8,12,13,16) Awareness of the importance of a closer collaboration with farmers (4,7,12,16)
	Human capital: Capacity building	Researchers become facilitators (1,7) Enhanced organizational management, leadership, planning, manage funds, record keeping (13,16) among `real world´ actors Local actor document the process (16,17) Participants desire to continue with the approach after project ended (8,10,16) Improvements of the process identified: activities modified after feedback and agreement of all participants, e.g. inclusion of new step in Participatory Monitoring &Evaluation (10), increased level of complexity in experiment and involvement of actors (7), validation of famers adoption choice (16) Self confidence among participants, e.g. farmers' interaction with other actors (6,16) Strengthening local institutions (9,16) and local capacities to self-organize and mobilize for collective action (9)
Increased action possibilities	Change in relevance system	Re-assess relevance of information (2,11) Discourses altered (16), through the joint effort to find a joint solution to the problem (7,11) Higher awareness of participants' and researchers' role in self-driven change (7,16) Farmers' active role in the process of change (16)
	Enhanced problem-solving capacity	Understand the complexity of the system (7,9,16), also by researchers (11) Identify and support innovations and locally adapted solutions (7,9,16,17) Co-generation of knowledge (16) Farmers' access to monitoring information (16), used as feedback for further knowledge creation (7,16) Identification of out-scaling possibilities and difficulties (10)

The numbers in brackets refer to the research project from which the example is drawn (see Table 1).

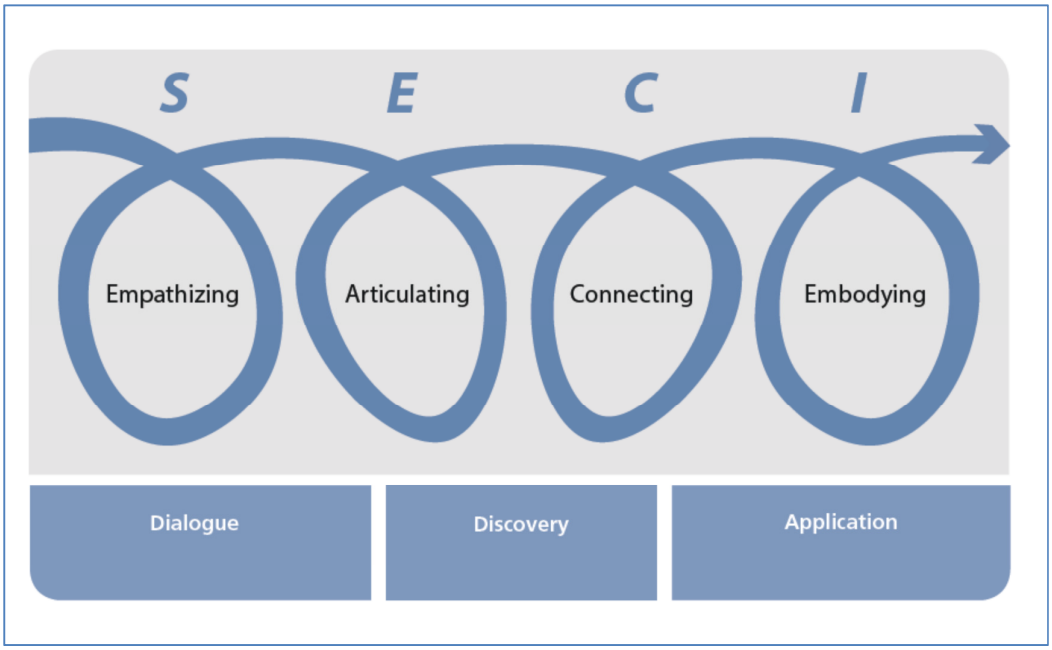

Figure 2. Knowledge spiral model integrated with the collaborative learning approach; SECI is short for socialization, externalization, combination and internalization of knowledge (Source: Nonaka and Takeuchi 1995, amended).

Only a few authors explicitly state criteria used for selecting participants. One example is Halbrendt et al. (2014) who selected participants based on consultation with a local NGO. Information regarding how a balanced group composition was achieved is also not specified. These observations point to the need to make the processes of actor identification and interaction more explicit.

There is further a risk to overlook heterogeneity *within* the different stakeholder groups and hence select 'representatives' that are not necessarily those who should be addressed in light of the problem at stake. Hence, caution needs to be exercised when assuming that a participant from a particular group can stand in for the perspective of the entire group. For this reason, it is important to detail how participants are invited to join a project and reflect why some may want to participate and not others.

Knowledge integration through the process of *dialogue* was achieved either by bringing together different perspectives or by encouraging a dialogue between holders of different 'knowledge types'. Transformative learning, and particularly a transformation of the participants' relevance systems, was achieved only after this dialogue had taken place. Totin et al. (2013) encountered that individual discourses of some participants were altered through the joint efforts to state a shared problem.

During the process of *discovery*, participants gained new experiences by testing new ideas, either in practice (e.g. co-inquiry and experimentation) or in thinking (e.g. scenario analysis). New information gained was in some cases augmented by implementing a monitoring system that included the use of various instruments and perspectives different from those regularly used (see Table 3). The new information was then analysed to better understand what was working or failing and in order to work towards consensus on ways to improve it. Examples are pathways to achieve visions developed in scenarios, or recommendations for the next season´s experimental work.

Following Kolb´s learning cycle (1984), *application of new knowledge* is a crucial part of the learning process. Learners do not only need to have an idea of improved practices, technologies or forms of organizations, but their implementation in practice may require new capacities and skills, or lead to new insights and modifications of the original 'solution'. However, science projects do not generally conceptualize the application phase as integral part of the research process, thus risking that a change of practice in the 'real world' cannot be achieved. Nonetheless, it appears particularly necessary for addressing sustainability issues in complex social-ecological systems, such as food and farming systems, because possible solutions may often need to be adapted and modified to finally 'fit' to highly diverse and unpredictable conditions.

The review of cases further suggests that trust building is a key element for the learning process to be successful. Trust among participants results from a well-structured and well-facilitated process where actors have sufficient time to arrive at a shared understanding of the problem and to work jointly on goals, tasks and activities. Initial clarification of roles and benefits from participating in the project diminishes opportunistic behaviour and unrealistic expectations. Developing a clear, iterative and concise communication system was also attributed as a trust-building mechanism, as stated by Krupnik et al. (2012). Collaborative learning approaches will thus additionally benefit from a deeper understanding of trust-building mechanisms.

Working in groups can help create new opportunities of expression and communication and thereby build trust. Moreover, it is known that participants are likely to strengthen their problem-solving capacities when working in groups (Vygotsky 1978). For instance, when actors gain insight into the complexity of the systems they work on, as reported by Podestá et al. (2013).

Overall, there is growing awareness of the importance of collaboration in change processes. This was evinced after the implementation of a Participatory Monitoring

and Evaluation (PM&E) system, which enabled researchers to conduct field experiments *with* farmers, and not merely on the farmers' fields (Nicetic and van de Fliert 2014).

A key outcome from the collaborative learning process is that actors perceive that they have gained something meaningful, especially when the goals of a project are aligned with their needs. If this was the case, participants were likely to continue the endeavour. A positive feeling of growth, improvement and satisfaction can even occur when it is not linked to tangible outcomes. For instance, participants in different studies expressed that they had benefitted by increasing their horizontal and/or vertical social networks.

Conclusions

In a collaborative learning process aimed at addressing 'real world' problems, diverse actors come together to resolve problematic situations that are beyond individual possibilities. Addressing these problems together and finding relevant solutions are key issues of transdisciplinary research. Collaborative learning, as proposed in this article, can thus be one way of implementing transdisciplinary research leading to change of practices in social-ecological systems.

The review of the papers points to the importance of the social interactions within the transdisciplinary research project. It shows the need to understand and apply trust-building mechanisms among the different actors. With time, participants' awareness of their roles in the process of creating change is strengthened, while awareness of the importance of collaboration increases. This collaboration between actors, and especially between academics and practitioners, improves the ability to respond, adapt and intentionally transform in relation to the complex problems found in food and farming systems.

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[1] The concept of social and human capital is based on Pretty and Ward (2001) and Pelling and High (2005).