Innovating in context: social learning and agricultural innovation

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Abstract: *Recognition of the complexity of challenges rooted in human-environment interactions has led to increased interest in methods that enable diverse stakeholders, from within and beyond the scientific establishment, to work together. Increasingly, agricultural innovation is understood in these terms, with calls for group learning processes that bring science and engineering stakeholders into contact with farmers and farmer knowledge. This perspective relates closely to social learning (SL) as a theory and approach in which cycles of knowledge sharing and joint action lead to the co-creation of knowledge, new or changed relationships, and changes in practice. While SL theory has been widely considered in literature concerned with natural resource management, the body of papers that link SL and agricultural innovation is surprisingly sparse. The papers included in the literature search presented here, identify a number of potential drivers and barriers to agricultural innovation emerging from SL processes. In particular, we identify the significance of: issue framing and agreement between actors about the role of the innovation; skills and capacity to do with learning as well as the use of the technologies; compatibility between existing practices and innovations; trust in innovations and other actors; and the facilitation of the process. Our paper shows there is a fundamental significance of SL to agricultural innovation, which can be operationalized by framing agricultural innovation as changes in understanding, practices and relationships. The use of SL as a design framework supports the emergence of agricultural innovations that bring equitable benefits, are sustainable and are innovated in context.*

Keywords: *Social Learning, agricultural innovation, process design*

Introduction

Interdisciplinary and co-produced research and learning are increasingly recognised as necessary if society is to meet the complex challenges of building resilience to environmental and social change (Tàbara, 2013). If the benefits of innovation and technology development are to be secured for sustainable and resilient agriculture and food production, this will mean moving beyond linear models of technology transfer. New methods are required to ensure the knowledge, motivations and interests of farmers and other stakeholders are integrated into innovation if desired impacts and shared goals are to be achieved (Roling, 2009; Klerkx et al., 2012; MacMillan and Benton, 2014; Jiggins and Visser, 2016). We found the body of papers that link social learning (SL), as a body of theory and practice concerned with building shared knowledge through co-learning, and agricultural innovation surprisingly sparse. In this paper, we explore the potential for SL to support this shift in innovation.

Contemporary calls for transformations in the relationship between the receivers and providers of scientific research and development build on a substantial history. In the early 1990s, Funtowicz and Ravetz (1994) proposed that a new 'post normal science' was necessary to meet the challenges of environmental change. Drawing on longstanding critiques that saw 'normal' science as narrowly apolitical, and responding to an emerging recognition of 'wicked' problems, this new view of science sought to draw in experts, policy makers and wider stakeholders as part of an 'extended peer community' (see Turnpenny et al., 2009; Turnpenny et al., 2010). The aim was to create an expanded science capable of tackling the complexity, uncertainty and contradictions inherent in interconnected social and environmental problems that include actors with diverse value systems. While Funtowicz and Ravetz (1994) and others (notably, Jasanoff, 2004; Nowotny, 2003) have focused on reshaping science, a congruent literature has been concerned with decision-making and governance (Hurlberg and Gupta, 2015; Chaffin et al., 2014). The need for interdisciplinary engagement, stakeholder participation and learning to address the complexity of change in social and ecological contexts has been recognised in literature concerned with diverse environmental and natural resource management challenges**.** Examples can be found in relation to (among others) climate change (Collins and Ison, 2009), water catchment management (Ison et al., 2007), farming and agriculture (Jiggins et al., 2016) and sustainability science (Lang et al., 2012). In each case, there is a recognition of the interconnections between social and ecological systems and – crucially – that multiple stakeholders, often with diverse perspectives, are implicated in defining and resolving problems.

This trend is increasingly evident in literature concerned with the social and environmental sustainability of food and agriculture. The challenges of climate change adaptation and mitigation, plateauing yields, increasing environmental degradation and livelihood vulnerability have prompted critical engagement with the mainstream model of intensification and commoditization (Pelletier et al., 2016, Rotz and Fraser, 2015). While an industrialised approach to agriculture has increased labour productivity, lowered food prices and, until recently, improved yields, the relentless focus on opportunities for profitable returns on investment in regional and global markets demonstrates "how deeply mired farming is in 'doing the wrong things, more and more efficiently'" (Jiggins et al., 2016, p218). As Jiggins et al. suggest, the problem is how current understanding and opportunities for learning frame challenges and opportunities for change. MacMillan and Benton (2014), writing in Nature, emphasise the scale at which agricultural innovation occurs. Mirroring patterns of concentration throughout the supply chain, agricultural research and development investment has been focused in a very small number of research centres and on high-technology instruments and techniques (MacMillan and Benton, 2014). Simultaneously, the diversity of knowledge and information has contracted as the power of commercial interests has increased in contemporary food systems (Rotz and Fraser, 2015). Innovation has become locked into a "one-size-fits-all approach" which neglects the fact that "how well crops and livestock grow depends on the interaction of genes, management and environment" (MacMillan and Benton, 2014, p.25). Thus, future gains in production will "depend ever more on innovating in context" (MacMillan and Benton, 2014, p.25) and on attendant issues of not only diverse ecologies, but also whose knowledge is valued, and how.

If MacMillan and Benton's (2014) "innovating in context" is to be achieved and the historic failures of farming addressed, the rules, norms and practices of innovation will need to shift. Central to this is co-learning to build new relationships, and to expand the scope of problem framings and the types of solutions that might be imagined in food production and the management of natural resources (Jiggins et al., 2016). Recognition of the diverse challenges of economic, social and environmental sustainability inherent to agricultural intensification has similarly prompted calls for farmers to become active in co-producing knowledge alongside research and technology specialists (Caron et al., 2014). Case studies reviewed by Pelletier et al. (2016) draw attention to the centrality of learning, and the role played by the broader social, institutional and governance context in enabling access to and exchange of knowledge among farmers and other stakeholders. These authors are by no means alone in highlighting the significance of relationships, information sharing, and capacity building and support for farmers to participate in processes of innovation and change (e.g. Kremen et al., 2012; Bullock et al., 2017).

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These arguments are reflected in Jiggins and Visser's (2016) synthesis of papers from the 2016 Symposium of the International Farming Systems Association. They conclude that there are three characteristics common across diverse examples of farms that have transitioned towards more sustainable natural resource management and farming systems. First, there is a focus on learning that allows knowledge to be developed through joint actions between stakeholders. Second, the changes being made are socio-technical and emerge from actors who have expanded the boundaries of their understanding, or redefined the purpose, of the system. Finally, reformed institutions and new relationships or networks are fundamental in enabling these changes. These observations have close resonance with research and practice associated with SL, understood as learning that emerges through practices that facilitate knowledge sharing, joint learning, and co-creation of experiences between stakeholders around a shared purpose (Ensor and Harvey, 2015). Some authors have observed that both innovation and extension in agriculture can secure the potential for change through SL (for example, Leeuwis and Aarts, 2011). In contrast to initiatives that focus on the creation and dissemination of information produced outside of the application context, a SL perspective on innovation focuses on building knowledge that is rooted in the local context and is equipped to capitalise on the skilled practice of farmers.

A large literature can now be identified in relation to social learning, much of which is concerned with how SL can be applied to problems of natural resource management (Rodela, 2011). Yet the antecedents of contemporary SL lie in concerns with the psychology of learning (Bandura, 1977), the sociology of learning in groups (Argyris and Schön, 1978) and, pertinently, attention to the social setting in which learning takes place (Lave and Wenger, 1991). This latter body of thought emphasises how culture, context and established practices influence – and are influenced by – any learning that takes place. As Ensor and Harvey (2015, p.510) summarise, "learning emerges from the collaborative processes that allow a shared sense of meaning to be arrived at by the community" and thus, those designing SL interventions "focus on enabling new meaning to be found through interaction with those who have a different perspective, in a process of shared 'sense-making' around particular issues or challenges". In this way, learning expands the boundaries of understanding among those stakeholders who are engaged in a SL process. The literature draws attention to the centrality of iterative engagement, interaction, openness, and facilitation (Muro and Jeffrey, 2008; Pahl-Wostl et al., 2008), and SL has been defined as "…the process by which societal actors interact and develop alternative perspectives on a societal issue" (Bos et al., 2013, p.399), although multiple definitions appear in the literature (recently summarised by Thi Hong Phuong et al., 2017). Here, we emphasise knowledge sharing, joint learning and the co-creation of experiences between stakeholders as central components of SL approaches (Ensor and Harvey, 2015) and note the proximity of these characteristics to those identified by Jiggins and Visser (2016).

So far we have explored the potential for SL as a framework for agricultural innovation. In the next section, we review the existing literature that brings together agricultural innovation and social learning, and find this overlapping literature to be surprisingly sparse given the shared perspectives outlined above. Our analysis offers a number of important findings that have emerged from within this shared literature, in particular in relation to the drivers and barriers of a SL-framed innovation process. We then discuss how SL opens spaces for agricultural innovation though changes in understanding, practices and relations between stakeholders. In concluding, we follow Colvin et al. (2014) in proposing the use of SL as a design framework to support the emergence of agricultural innovations that are sensitive to context, equitable and sustainable. Our understanding of innovation in this context refers not just to ideas but also "new processes, institutions or ways of working that aim to meet a set of needs or tackle a set of problems" (Colvin et al., 2014, p.761).

Method

A search in Scopus that looked for the presence of the words agricult*, innovation* and "social learning" within the title, abstracts or keywords of papers (TITLE-ABS-KEY agricult* AND innovation* AND "social learning") resulted in 45 entries on 16 February 2017. An initial review of abstracts filtered out non peer-reviewed books. Articles that looked at innovations in virtual platforms and games, sanitation, or policy schemes such as Payment for Ecosystem Services, were excluded as we were interested in SL in relation to on-farm innovations. Articles were also excluded when they were not focussed on SL of farmers, but for example focussed on SL of vendors or institutions. This process reduced the number of entries to 22, therefore excluding 23 entries. The articles were subsequently assessed in more detail to make sure that the focus on SL was more than superficial and was on SL as defined above, for example by ensuring that when introducing SL the authors cited at least one of the main papers connected to the body of literature we refer to in the introduction of this paper. This excluded an additional 10 papers, leaving us with 12 papers for the analysis that are summarised in Table 1.

Table 1. Summary of papers included in this analysis.

Nr.	Citation	Year	Case study context	Country
1	Akpo et al., 2015	2015	Innovation in palm-oil seeds growing practices through learning group process with farmers and other stakeholders	Benin
2	Beers et al., 2014	2014	New Mixed Farm innovation project and their communication with external stakeholders	Netherlands
3a 3b	Dogliotti et al., 2014 Rossing et al., 2010	2010 2014	Improving the sustainability of family farms	Uruguay
4	Eastwood et al., 2012	2012	Dairy farms and uptake of a digital decision support system	Australia
5	Hermans et al., 2013	2013	Innovation in network of dairy farmers	Netherlands
6	Hermans et al., 2015	2015	Learning outcomes of innovation networks for sustainable agriculture (LINSAs)	8 European countries
7	Kroma, 2006	2006	Evolution of organic farming networks	USA
8	Oreszczyn et al., 2010	2010	Evolution of network of farmers interested in using genetically modified (GM) crops	UK
9	Schneider et al., 2012	2012	Evolution of no-tillage farming	Switzerland
10	Thorburn et al., 2011	2011	Decision support systems in sugarcane production	Australia
11	Tisenkopfs et al., 2014	2014	Changes in framing within network of fruit growers and biogas	Latvia
12	Wals and Rodela, 2014	2014	Editors' reflections on special issue, including Beers et al. (2014)	n.a.

All papers included in this analysis describe case studies. Cundill et al. (2014) suggest the case study is a useful scale of analysis as it recognises that learning and change processes take place due to and in relation with a social-ecological context. They therefore need to be explored in relation to that context. The paper by Dogliotti et al. (2014) that came up in our search, referred to another paper by Rossing et al. (2010) that described the innovation process in more detail. We have included this paper on the grounds that it would help draw out more insights about the process that was used.

Table 1 shows how the 12 resulting papers have been published relatively recently and have a limited geographic spread. They refer to a wide range of agricultural innovations, from innovations in farming practices (organic farming (Kroma, 2006), no-tillage (Schneider et al., 2012), family farm practices (Dogliotti et al., 2014), and palm-oil seeds growing practices (Akpo et al., 2015)), decision support systems (Eastwood et al., 2012 and Thorburn et al., 2011) and networks of innovation (Tisenkopfs et al., 2014; Oreszczyn et al., 2010; Hermans et al., 2013; Beers et al., 2014; Wals and Rodela, 2014; Hermans et al., 2015). All papers reflect on the context of the agricultural innovation within their case study, however in four papers (Oreszczyn et al., 2010; Dogliotti et al., 2014 and Rossing et al. 2010; Thorburn et al., 2011; Akpo et al., 2015) the authors describe an intervention in which SL was used as a fundamental principle in the design of innovation activities. In the following, we analyse these 12 papers in terms of the drivers and barriers to innovation and learning revealed, and the interconnectedness between the social and technical. In particular, we identify the significance of: issue framing and agreement between actors about the role of the innovation; skills and capacity to do with learning as well as the use of the technologies; compatibility between existing practices and innovations; trust in technologies and other actors; and the facilitation of the process.

Drivers and barriers to innovation

The papers included in the analysis identify a number of potential drivers and barriers to agricultural innovation emerging from SL processes. These factors often highlight the interconnectedness between the social and the technical. Table 2 summarises the main drivers and barriers to agricultural innovation found within the 12 papers, each of which are explored in more detail below. Not all barriers and drivers were present in all papers, in part due to the different focal points of the studies. For example some studies did not include specific technological innovations, but looked at innovation networks and were therefore silent on the driver of compatibility between practice and technology.

Table 2. Drivers and barriers to innovation identified in the reviewed papers.

Drivers / barriers
Issue framing and agreement / Failure to agree between actors
Skills and capacity / Lack of skills and capacity
Trust and credibility / Lack of trust or credibility
Compatibility / Incompatibility between practice and technology
Facilitation / Lack of facilitation
Presence / Absence of an intermediary

An agreement between actors within an innovation process of what the issues are that need to be addressed is critical to innovation and a failure to agree makes innovation more difficult. Tisenkopfs et al. (2014) suggest that alignment of framings is a pre-condition for collective action. They reflect that divergent and conflicting viewpoints hamper broader agreement between actors. In eight European countries Hermans et al. (2015) found a fragmented vision of sustainable agriculture in national level innovation networks. This lack of agreement, they considered, has led to competition and limits collaboration in innovation networks. Beers et al. (2014, p.10) found that “a fundamental clash of value systems” led to a deadlock between the actors involved in and those external to an innovation project that aimed to set up an intensive farming unit. In particular, there was no shared understanding of value of the innovation between the entrepreneurs and local public and national environmental organisations. The entrepreneurs were convinced “that upscaling was necessary for more sustainable agriculture”, whereas the opponents questioned “whether large-scale agriculture could be sustainable at all” (p.10). Recognising that both sides were focused on their own arguments instead of learning from each other, the authors suggest that any innovation experiment needs to increase its “awareness of and sensibilities for” (p.11) the societal environment. They go on to say that if SL among different groups is possible then stakeholders should be brought together from the start. However if, as they thought was the case here, the underlying values are so strong and different it may not be possible to “socially learn one’s way out of a deadlock” (p.11).

Processes that support an exchange of ideas and the co-construction of issues of significance are reported to enable learning to take place. In the case of (Dogliotti et al., 2014) stakeholders became aware that innovations that implied an increase in labour demand would not succeed on family farms in Uruguay due to limited labour availability. Instead stakeholders reframed the focus of the innovation process to labour productivity and were able to make improvements to the sustainability of participating farms. Thorburn et al. (2011, p.324) also found that different beliefs and expectations about the technology of the innovation, or “incongruent technological frames”, were a barrier to the use of a new decision support system tool. They found that after their SL process finished “there remained a degree of incongruence among the technological frames of the case study members” (p.330). Some participants didn’t see the need to change their practices, others felt it wasn’t possible to make changes based on their new understanding (an incongruent technological frame), whilst other members said they had improved their understanding and said they would continue to use the innovation (a congruent technological frame).

Having the **skills and capacities** to undertake or join SL processes is also an important factor. Hermans, et al. (2015) point out that not all farmers are as capable to formulate their information needs to stakeholders who could offer advice, especially in countries where formal agricultural training is limited. This makes it difficult for farmers to link up with innovation systems. Kroma (2006) suggests “enhancing farmer capacities for critical enquiry” and creating space for “alternative conceptualisations” (p.13) are critical for SL to take place. Akpo et al. (2015), in their case of palm-oil seedling production practices in Benin, found that the ability and willingness of stakeholders to “transcend personal interest” (p.371) enabled stakeholders to gain a shared understanding of the issues. Other skills are related to the technology at hand. Eastwood et al. (2012) reflect that having ICT skills greatly helped the steep learning curve farmers faced at the beginning of using a precision dairy farm system. In the case of Akpo et al., (2015) they went through a process of co-designing not only an innovation experiment, but also the indicators used to monitor and evaluate the results. Through the process participants learned new skills to observe and analyse the experiments in an academic way. Training can also be provided to overcome a lack of skills. Beers et al. (2014) suggest that innovation projects have to be aware of their external environment, otherwise the projects cannot respond to changes in that external environment. However they recognise that not all innovation actors will be able to learn together with external actors and may either need training or support from other people, such as a facilitator, to increase their capacity for SL.

All papers mention **trust** as fundamental to SL and innovation. This includes trust in other actors within the network as well as trust in the technology. Examples of the first are offered by Tisenkopfs et al. (2014) who conclude that trusting relationships within a network are key to support frame convergence. Kroma (2006) reflects that farmers have most trust in each other, although Oreszczyn et al. (2010) note that farmers are most influenced by people other than their peers. The latter describe how trust in the government changed over time due to increasing regulations that seemed to farmers to indicate a lack of understanding of how a farm works in practice. The breakdown in trust proved a barrier as it made farmers suspicious of information provided by government. Hermans et al. (2015) suggest that farmers have to navigate competing knowledge providers since the privatisation of extension services, which has made it harder to know what advice to trust, especially when offered ‘free’ advice from companies and advice from research that a farmer has to pay for. Oreszczyn et al. (2010) also found that farmers felt frustrated with the increasing number of official guidelines and policies. Similarly Hermans et al. (2015) identified factors that influenced collaboration in agricultural innovation systems (AIS), including “overregulation of innovation policies” (p.45), decreasing trust between government and farmers, and “vertical and horizontal fragmentation” within an AIS (p.47). These have led to a risk-averse and short-term focused innovation context in which, the authors say, collaboration and SL have become difficult.

Trust in a new technology is illustrated by the cases of two decision support systems. Thorburn et al. (2011) highlight that respect for different knowledges and contributions from different actors within the iterative process of developing a decision support system were critical to the collaboration between otherwise disparate stakeholders. They also point out that credibility is key when effectively using ‘boundary objects’, such as decision support systems, within a learning process. They found that boundary objects are useful facilitators of co-learning between diverse stakeholders. However, trust in the technology can also be undermined, especially when there are faults in the early learning stage, as Eastwood et al. (2012) found. This undermining of trust affected farmers’ continued use of the new technology.

Compatibility between existing practices and innovations is also mentioned as a key driver or barrier. Eastwood et al.'s (2012) longitudinal study of precision dairy farming demonstrates that the (un)compatibility of new technology, data and processes with existing or older data sources and practices can be a fundamental barrier to continued use. This is as much a facet of the technology being embedded in a socio-technical system, where the ‘social’ component is central to success or failure. For example, when compatibility was low the new technology was generally used only to a small extent. Some users, however, were willing to make changes to their own practices to fit around the new information system. These individuals were actively engaged with the system, determined to reap benefits, and had a willingness to experiment. On the other hand, the shift to centralisation of data associated with the precision system interrupted established flows of information and knowledge exchange between members of the farm management teams. This made it harder to keep the system up-to-date, undermining potential benefits. SL can also support compatibility of practices between stakeholders. In the case of palm-oil seeds production in Benin, Akpo et al. (2015) describe how nursery holders changed their practices to better fit with the practices of farmers who plant the seedlings. This process influenced the official advice provided by the government to nurseries, leading to a systemic change of increased compatibility.

Table 3. Different names for the role of intermediary within an innovation network.

Name for an intermediary within the network	The role of that intermediary	Nr.	Citation
Researcher	Creator of a social space and supporting a space for experimentation	1	Akpo et al., 2015
Project monitor	Helps to monitor the learning process	2	Beers et al., 2014
Coalition builders	Researchers who were considered to be committed to the local farmer’s context and who frequently visited the farms	3b	Rossing et al., 2010
Translators	Sit between technology and agriculture	4	Eastwood et al., 2012
Innovation brokers, inter-organisational brokers, systemic brokers	Inter-organisational brokers support the outscaling of innovation and systemic brokers who shape the innovation network itself	5	Hermans et al., 2013
Extension Associates	Integrate farmers’ experiences and understanding with scientific understanding	7	Kroma, 2006
Brokers or boundary spanners, roamers, outposts or pairs	Span the boundaries between farming networks of practice and other communities or networks of practice	8	Oreszczyn et al., 2010
Mediating human and non-human actors	Transform and translate different knowledges	9	Schneider et al., 2012
Boundary objects	The decision support system facilitated the conversation between actors and translation of different knowledges.	10	Thorburn et al., 2011
Frame openers, frame alignment facilitators, boundary spanners and peacemakers	Provide safe and neutral learning spaces, embrace all interests of actors and invite people into a process	11	Tisenkopfs et al., 2014

Facilitation is considered a key element of agricultural innovation emerging from social learning processes. In the four papers that discussed an intervention facilitation was a fundamental part of their approach. Facilitation was linked to process design, ensuring the transparency of the process, and creating space for interactions between stakeholders which can be seen as social spaces for experimentation (Akpo et al. 2015).

In most papers the role of an intermediary could be observed. Table 3 shows how different authors referred to this role. Kroma (2006) is the only study that mentions extension associates whereas others see the role of intermediary as an option for any actor in a network. In reflecting on the theory of SL, she mentions extension services as having a particular mediating role in agricultural innovation by being the channel through which science was able to diffuse innovation and knowledge. There is a need for changes of a systemic nature in how these services connect and interact with farmers and technologies. She argues for increasing extension services' capacity as facilitators of group processes, away from what she calls "a narrow focus on technology supply and behaviour change of the individual farmer." (p.24)

The intermediary, as described in Table 3, aims to facilitate changes in understandings through bringing together different actors and supporting or translating different knowledges. Tisenkopfs et al. (2014) suggest that through interaction between stakeholders and through exposing people to "real lived worlds of others" (p.324), people's initial framing of particular issues or problems can change and can result in co-constructed expressions of alternative conceptualisations of challenges or problems. Oreszczyn et al. (2010) refer to Etienne Wenger to note that practice develops and takes place within a context of people exchanging ideas and that together they negotiate meanings and understanding. Akpo et al. (2015) found that the experience of working together and evaluating an experiment they designed together, offered a deeper and shared understanding of each other's practices. Stakeholders better appreciated the pressures the other stakeholders were under and were able to renegotiate what 'good' production meant, taking into account the larger supply chain in addition to their own distinct part of it. This underlines the importance of an intermediary who can enable a facilitated process where actors are exposed to other people's lives and knowledges and innovate together.

Agricultural innovation as social learning: changes in understanding, practices and relationships

In taking a SL perspective on or approach to agricultural innovation, the 12 papers suggest different changes that emerge in relation to a social or environmental context and via a mediating innovation. We have identified three categories of change that are interconnected and overlapping: changes that occurred in understanding, in practices, and in relationships. These changes are the intended outcomes of a design informed by SL. For example, Collins and Ison (2009, p.367), in proposing a "design heuristic for social learning" note (i) that learning processes, which are central to affecting transformations, arise though changes in understandings or practices of those involved; and (ii) that this transformation process gives rise to changes in social relations between stakeholders. Crucially, it is this process of transformation that opens spaces for innovations to emerge that are responsive to context and respectful of a plurality of knowledges embedded in differing epistemological backgrounds (Colvin et al., 2014). As Table 4 illustrates, while all papers record changes in relational learning, some cases do not reveal changes in understanding or practices. This is as the focus is in Beers et al. (2014) on the response of an innovation experiment to the societal context; in Hermans et al. (2015) on national level innovation networks; and in Wals and Rodela (2014) on different disciplinary perspectives to address sustainability challenges.

Table 4. Papers that reflected on changes in understanding, practices and relations.

Learning processes arose through…	Cited papers
… changes in understanding … changes in practices	All except: Beers et al., 2014; Hermans et al., 2015; Wals and Rodela, 2014
… changes in relations	All papers

Changes in understanding come about when different knowledges meet in a process of co-creation. The papers illustrated the changes in understanding that emerged by providing evidence of re-framed issues or of newly shared understandings of issues. In the case of Tisenkopfs et al. (2014) re-framing was illustrated by the changes in what was considered a 'good' apple variety in Latvia. Stakeholders were brought together in a process of SL. This included researchers who had, prior to the SL intervention, dominated the framing of the 'good' apple variety from a scientific perspective. Also included were practitioners who framed the apple varieties from the perspective of how easy or difficult these were to grow and harvest, and retailers who framed the varieties from a taste perspective. This process helped to broaden understanding beyond the scientific framing. Similarly what was considered to be a 'good' quality oil palm seedling differed between stakeholders in the case reported by Akpo et al. (2015). The different understandings of quality were negotiated in an SL process between nursery stakeholders and farmers who bought the seedlings from the nurseries, leading to changes in policy guidelines for other nurseries. Schneider et al. (2010) explore how, since the middle of the 20th century, different actors in Switzerland have reshaped what the concept of no-tillage means. Initially framed as not always using a plough, it developed into a way of life. More recently no-tillage has become an integral part of organic farming illustrating yet again another understanding of the concept.

Evidence of newly shared understanding is provided by two cases in which insights of some are tested or validated by others. The farmers in Kroma's (2006) case study belonged to the organic farmer networks in order to share learned lessons from experiments with each other so that they could validate and test their understandings. Hermans et al. (2013) describe how co-creation of knowledge occurred when scientists validated and tested the knowledge claims of farmers. As these examples suggest, an SL process is one that is designed to help stakeholders come to a deeper understanding of other perspectives, and offers a space where, and processes through which, views can be reshaped into a shared understanding.

Changes in understanding also emerge when different knowledges come together and are negotiated in the presence of new technologies and systems. Thorburn et al. (2011) illustrate how understanding changed due to a process that used a new decision support tool, which brought together different knowledges. Eastwood et al. (2012) present a case study of dairy farmers who invested in precision dairy through the adoption of automated information systems, following their learning process from pre-installation through to two years post-installation. The use of a precision dairy system meant a steep learning curve for the participating farmers. It required farmers to translate their own understanding of the farm into the format and forms of data required by the system setup; conversely, the farmers needed to interpret data coming from the system into their farm context. Farmers had to merge existing tacit knowledge with new explicit knowledge from the precision system.

An SL process does not necessarily lead to reframed perspectives of all stakeholders. In the case studied by Rossing et al. (2010) and Dogliotti et al. (2014), which aimed to improve family farming in Uruguay, the SL process focussed on diagnosing the problems on each farm. This involved bringing together scientists (who used quantitative modelling) and the farmers during field visits and interviews. The authors conclude that the process led to a deeper understanding and a better diagnosis of problem factors on each farm. They describe how researchers became 'systems scientists' who considered other components of the agricultural system within their disciplinary models and 'remoulded' their initial ideas through this negotiation process with the farmers. However, Dogliotti et al. (2014) point out that despite this SL process, some of the on-farm changes proposed by the researchers were not supported by the farmers. A recording system did not fit with farmers' skills and priorities, and in interviews the farmers expressed that they saw this new system as a project imposed chore. While the researchers went through a process of re-framing their perspectives, the results suggest that the farmers did not share this new understanding. Similarly, in the precision dairy case study presented by Eastwood et al. (2012) not all participants had the opportunity or skill set to improve their understanding. Some farmers were not as willing as others to 'play' with the new system, and not all were equally able to interpret the new data provided by it. The new system also introduced different degrees of access to the data: those who could only upload data and those who were also able to access and analyse the data. In farms were previously everyone had had access to the records, the new system resulted in a more centralised knowledge system. This improved the understanding of those with access to the system, but did not support those without.

An SL lens also draws attention to **changes in practices**. Several of the case studies conclude that practices have changed due to the SL process. In some cases these are changes in agricultural practices in the field. In the case study in Uruguay changes were observed in crop rotation practices that took into account multi-year planning, a new longer term approach to farming that wasn't used before (Rossing et al., 2010; Dogliotti et al., 2014). Kroma (2006) observed experimentation with new ideas in organic agricultural practices in the USA, Schneider et al. (2010) described changing practices to do with no-tillage and the case study of Akpo et al. (2015) reported on changes in palm-oil seed production practices at nurseries. In other cases changes in practices referred to the use of (new) technologies, including information systems and crops. For example Eastwood et al. (2012) describe the uptake and use of precision dairy systems in Australia, Thorburn et al. (2011) report the use of a decision support system for sugarcane production in Australia, Hermans et al. (2013) focus on farmers in the Netherlands who developed a landscape management approach to dairy farming, Oreszczyn et al. (2010) describe the uptake of GM crops in UK agriculture and Tisenkopfs et al. (2014) show how new apple varieties were grown and sold in Latvia as a result of the SL process.

The use of a new technology can constitute a 'change in practice', but this should not disguise the fact that a change in practice of this sort can be the starting point of a deeper and longer process of learning. It is the continued learning that takes place after the uptake, where farmers and technologies interact in an on-going process, where further learning may occur. In the case study presented by Akpo et al. (2015) not only did palm-oil seed production practices at nurseries change, but the insights influenced the training guidelines the government offered to nurseries, catalysing continued learning and changes in practices in other nurseries. Eastwood et al. (2012) emphasise that the use of technology is really only the beginning of a learning process. They propose early learning, consolidated learning and adaptive learning as distinct categories that, in sequence, describe the shift towards more fundamental changes over time in people's lives and the collaborative learning between people and technology. 'Early learning' consists of a phase of data entry and use of the basic functionality of the new technology, as well as a steep learning curve to adapt routines and practices to fit in with the new system. 'Consolidated learning' refers to a phase of knowledge consolidation through repetition of tasks and building skills and capacity to be able to use the information from the system. The 'Adaptive learning' phase is when the farmer inputs different data, increases the opportunities for automated decision making and links with other users on- and off farm. It also changes the system from a diagnostic tool into a tool that can help farmers to predict issues. These case studies highlight the importance of the focal timescale when considering the changes in practices as a result of SL processes. The influence SL has, through the changes in understanding as well as the initial changes in practices, continues to reverberate within the social and environmental context in which these processes take place.

Finally, SL is associated with a **change in relationships** within a social and environmental context and via a mediating technology. All case studies reported on changes in the network surrounding the particular issue, agricultural innovation and/or context. Stakeholders, including human and non-human actors (e.g. animals, machinery, information systems), have come together in new constellations as new technologies came into play or political and financial institutions changed. Two case studies that describe a longitudinal assessment of changes in relationships are Kroma (2006), who documents changes amongst organic farmers and their practices in Organic Farmer Networks in the USA, and Schneider et al. (2012), who describe the evolution of no-tillage within Switzerland. The latter case study offers insights into the "process of co-creation of innovation" (Schneider et al., 2012, p.251). It explores how the concept of no-tillage brought together different actors over the course of more than 60 years and how these actors at different points in time reshaped what no-tillage meant in practice. It is through changes in relationships, extending the peer community through working together with actors with different knowledges and practices, that SL can offer a platform of shared experience.

The reviewed literature highlights how changes in understanding, practices and relationships secure opportunities for innovation, which are the central aims of SL. We note however that there remains a substantial body of experience captured in the wider SL literature, which could bring additional insights in support of the design and assessment of agricultural innovation. Examples that go beyond findings in the existing literature linking SL and agricultural innovation include: the need to keep a close watch on power relations and forms of social difference, including the potential for less powerful actors to be co-opted in shared decision making (Ensor and Harvey, 2015) and the significance of context (how the history and initial starting conditions can enable or constrain future trajectories), stakeholding (how understandings of what is 'at stake' can build stakeholder legitimacy in an innovation process), and institutions and policies (how established norms enable deliberation of an issue, but may also be challenged by the outcome) to the design of SL processes (Collins and Ison, 2009).

Conclusions

In this paper we identify a growing consensus for wider participation in agricultural innovation, and highlight how SL processes offer a multi-stakeholder forum in which knowledge sharing, joint learning and the co-creation of experiences between stakeholders are central. While the SL literature emphasises the transformations in understanding, practice and relations that constitute 'learning' in these processes, some authors have noted the potential for such changes to open the space for innovations that transcend established ways of knowing and doing. Our review of the literature that links agriculture innovation and SL has demonstrated that there is an emerging body of research and practice that sees value in a SL framing. These cases reveal barriers and drivers for innovation, many of which expand those explored in the SL literature by explicitly addressing concerns that arise from the social setting in which technical innovations are situated. Our paper shows there is a fundamental significance of SL to agricultural innovation, which can be operationalized by framing agricultural innovation as changes in understanding, practices and relationships. The use of SL as a design framework supports the emergence of agricultural innovations that bring equitable benefits (through the inclusion of otherwise marginalised stakeholders, their knowledge and interests), are sustainable (through shared learning, that transforms understandings of situations), and are innovated in context (responding to the relational and material realities of farmers).

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