Variable Collaborative Learning Spaces in the Quest for Agricultural Sustainability in New Zealand

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Abstract
Participatory research is advocated for fostering multi-stakeholder engagement and learning necessary for advancing sustainability. This work examines how participatory projects develop collaborative learning to advance agricultural sustainability. It presents findings from empirical evidence from six micro-level horticultural innovation projects in New Zealand where farmers and scientists engaged in public / private funded partnerships. Analysis revealed institutions, partner relationships and learning were critical and highly inter-related dynamics of participatory research projects. This paper focuses on the creation of learning spaces in these projects that ideally should support and sustain change to more sustainable practices. The research revealed a 'collaborative learning space' influenced by the strength of partner relationships and institutions that shape how actors engage in participatory research. This paper visualises the variability of the collaborative learning space among the six projects and reveals the importance of this space where innovations can be co-developed and learning is emergent, adaptive and dynamic.

1. Introduction
Nearly thirty years after the publication of the Brundtland Report (WECD, 1987), which sought global consensus around sustainability, the implementation of sustainability remains a highly fraught and contested endeavour. Within agriculture there remains an urgent need to effectively address the environmental impacts of agricultural practices. This requires effective responses at all levels, including at the micro-level - the "multi-party collaboration processes in which representatives from different stakeholder groups interact" (Medema, Wals, & Adamowski, 2014: 27).

Participatory approaches in agriculture are approaches to research that see farmers and scientists collaborate in projects to address a shared problem using both local and scientific knowledge. They are argued to be a suitable platform for facilitating change towards sustainability as they encourage multi-stakeholder engagement, collaboration, learning and collective action (Neef & Neubert, 2011; Pretty, 1995; Reed, 2008). Policy and funding agencies increasingly support the use of participatory approaches to both promote sustainable agriculture and increase adoption of sustainable innovations (Ison, Roling, & Watson, 2007; Pahl-Wostl, 2002).

Despite wide support for participatory research there remains limited understanding of how participatory research can stimulate meaningful change towards sustainability in the rural sector. Furthermore the integration of scientific and local knowledge in research projects is often difficult to achieve (Allan, Nguyen, Seddaiu, Wilson, & Roggero, 2013; Neef & Neubert, 2011). This raises questions about the effectiveness of participatory research for advancing sustainability. This paper uses empirical data from six micro-level innovation projects in New Zealand, where farmers and scientists engaged in public / private partnerships, to explore how participatory research fosters learning environments to advance sustainability.

2. Participatory Research in Agriculture

Post Normal Science (Funtowitiz & Ravtez, 1994) demands new approaches to research to address not just the technological requirements of environmental issues but also their socio-ecological complexities. In this environment, science is seen to be more democratic and socially accountable as it embodies multiple perspectives from inside and outside science and technology in decision-making (Gibbons, 1999; Lubchenco, 1998). Within this context, participatory research is put forward as an effective approach for multi-stakeholder engagement to address sustainability and to promote rural change, as it is inherently collaborative and inclusive by seeking to bring a wide base of expertise to both identify problems and co-develop solutions (Leeuwis, 2004; Pretty et al., 2010; Reed, 2008; Vanclay & Lawrence, 1995).

Participatory research challenges traditional ways of undertaking agricultural research and extension that favoured linear top-down approaches that saw agricultural scientists determine priorities, develop technologies and then transfer the knowledge to leading farmers through extension workers (Leeuwis, 2004). Participatory approaches no longer see science as the only legitimate knowledge for to do so denies the socially constructed nature of knowledge production. Participatory scholars call for divergent stakeholders to create shared understandings of problems and co-produce knowledge and solutions (Baars, 2011).

To advance sustainable agriculture, collaborative multi-stakeholder engagement and learning in 'transdisciplinary' participatory partnerships should challenge assumptions and values of both farming and science practice to facilitate new ways of thinking through a process of cumulative and incremental learning (Keen, Dyball & Brown, 2005; Roling & Wagemakers, 1998). Success however, must not be solely measured by quantitative indicators as this risks allowing a participation dogma to dominate, where success is solely measured by numbers rather than by the development of meaningful and lasting change (Vanclay, 2011; Ziegler & Ott, 2011).

In participatory research, learning should become an emergent property of the collaboration (Ison, 2005). The knowledge that is obtained from practical experience and collaborative experimentation is then built into solutions (Blackmore, 2007), with decision-making being collectively framed through dialogue (Leeuwis & Aarts, 2011). Leeuwis and Aarts (2011: 27) call the environment where people interact "a space for change" and highlight how this space is necessary for stimulating innovation in complex systems. They argue that these spaces mobilise divergent "discourses, representations and storylines" that fluctuate between the dominant thinking and new ways of knowing and doing.

The literature is emphatic that participatory projects should focus on the capacity of actors to learn together to enable problems and solutions to be co-constructed. Such 'constructivist' notions of learning are not focused on didactic approaches to teaching or persuading people to simply adopt an innovation. Instead they seek to bring about transformations in people's perceptions and assumptions (Keen et al., 2005; Mezirow, 1994) that ideally leads to a questioning of the underlying assumptions that drive current practice, which can generate new ways of knowing and doing. It is this type of learning that is regarded as essential for addressing the complexity of sustainability (Keen et al., 2005; Lachlan CMA, 2013).

Participatory approaches inherently require traditional power structures, with scientists as experts giving "top-down" advice to farmers as passive recipients, to be replaced by more equitable partnerships. While power sharing is regarded as a fundamental principle of participatory approaches, processes are however, often still affected by power structures. Kothari (2001) argues that an unquestioning approach to participatory endeavours can overlook the socially embedded nature of knowledge production and actually reinforce power differentials. Agencies adopting participatory approaches are criticised when superficial approaches to participation ignore the socio-political context of stakeholder interactions (Kothari, 2001; Pretty, 1995).

Redistribution of power structures will require fundamental changes to institutions that have historically afforded western science a privileged position in agricultural research and extension (Fergus & Romney 2005) and shape how scientists behave and practise science (Klerkx & Leeuwis, 2009; Ziegler & Ott, 2011). Indeed new approaches to research will challenge how scientists view themselves and science's role in research (Roderiguez, Molnar, Fazio, Sydnor, & Lowe, 2008).

However, community, funding and policy actors may perceive participatory initiatives as vague. Participatory researchers often struggle with the requirements of funding agencies which rely on evaluation measures more suited to the traditional top-down approaches to research and extension (Webber & Ison, 1995). Furthermore, among policy agencies there may be a primary expectation that participatory approaches will increase the acceptance of stakeholder adoption of innovations and government policy. Barr and Carey (2003) contend that the language of contemporary policy remains embedded in the Innovation Diffusion Model (Rogers, 1962), which sees innovation as inherently good for farmers (Ison, 2005), and assumes farmers will eventually adopt. Bruges and Smith (2007) even question the appropriateness of using participatory approaches to achieve policy goals that promote change towards sustainable agriculture.

3. Investigating Participatory Projects

New Zealand's farming and science landscape provides a rich context to examine how effectively participatory projects facilitate learning environments to advance agricultural sustainability. While farming remains a dominant force in New Zealand's economy (PCE, 2004), as with other countries, its rural communities face increasing pressure to address concerns about the detrimental environmental impacts of farming practices, with growing concern that the agricultural sector is underperforming in improving its environmental performance (PCE, 2004).

New Zealand policy and funding agencies have increasingly challenged scientists to build greater capability for participatory approaches into science research. Since the restructuring of New Zealand's science sector and the dissolution of publicly funded agricultural extension in the 1990s, many micro-level public / private 'participatory' partnerships have emerged to address sustainability.

The six micro-level projects investigated in this research supported engagement between science and farming actors in research partnerships and therefore were all generally consistent with the participatory paradigm. However, with no clear blueprint on how a participatory approach should be applied, implementation is variable. All were situated in the horticultural and arable sectors and located as shown in Figure 1. Five projects were partially funded by the government's Sustainable Farming Fund (SFF) with matching contributions from project farming partners. One project, Crop Science for Maori, was fully funded by the government's public science fund. Table 1 provides a synopsis of each project's objectives, while Table 2 outlines the characteristics of the farming groups and sectors, as revealed from project documentation. While all projects involved scientists and farmers working together to advance sustainability, their distinct differences provide valuable comparisons to assess learning in participatory projects.

Figure 1: Geographical location of projects

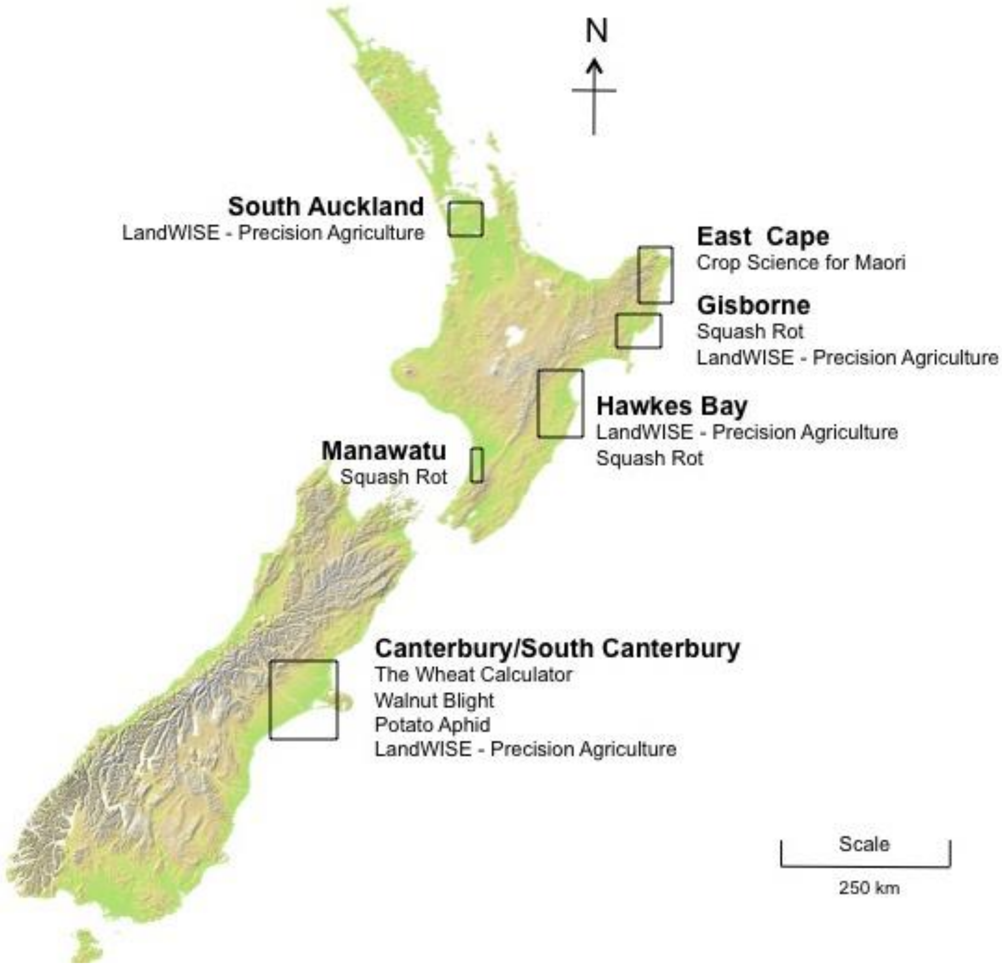

Table 1: Synopsis of project objectives, actors and project initiator

Project / Actors / Initiator	Objectives
<u>Crop Science for Māori</u> (5 year project with 1 year extension) **Actors**: Scientists & the East Coast Organic Producers (ECOP) Trust	• Identify how Māori communities could transition from extensive agriculture to intensive organic horticulture. • Establish a reciprocal learning network providing scientific, education, and extension services to enable ECOP Trust to develop and implement 'best' organic vegetable farming practices.

Initiator: jointly initiated by community and scientists	
<u>**Squash Rot**</u> (3 year project) **Actors**: Scientists & Squash Industry Group (Horticulture NZ), squash farmers & pack-house owners. **Initiator:** Scientists	• Assess factors that influenced the extent of storage rot in squash (buttercup) fruit lines. • To develop a model of weather influences on squash growth and yield to assist with defining multi-factor influences on fruit yield and maturity.
<u>**Potato Aphid Project**</u> (3 year project) **Actors**: Scientists & Potatoes New Zealand (Horticulture NZ) & farmers **Initiator:** Scientists	• Develop a pest management strategy to delay or prevent aphid insecticide resistance in potatoes to maintain options for pest control and potato quality. • Determine 'best practice' for the control of aphids and viruses in potato crops, and provide growers up to date information on aphid flights and infestation.
<u>**Walnut Blight Project**</u> (3 year project) **Actors**: Scientists & Walnut farmers from the Walnut Industry Group (WIG) **Initiator:** Farming Group (WIG)	• Optimise the timing of copper-based sprays and understand and transfer best practice blight management to growers. • Develop an environmentally benign agent for blight control to reduce reliance on copper-based sprays.
<u>**The Wheat Calculator**</u> (3 year project) **Actors**: Scientists & Foundation for Arable Research (FAR) & farmers **Initiator:** jointly initiated by FAR & scientists	• Examine and quantify the effects of arable and vegetable growing practices on nitrate leaching. • Development of "user-friendly" software - the Wheat Calculator, to provide information on how wheat cultivars respond to nitrogen loadings and irrigation. • Increase farmer profitability by increasing yields & reducing farm inputs & improving environmental outcomes by limiting the effects of nitrate leaching.
<u>**Precision Agriculture Projects**</u> (3 year project & 1 year project) **Actors**: LandWise working with LandWise farmers, researchers, arable & vegetable industry partners. **Initiator:** Farming group (LandWise)	• Co-ordinate on-farm research & development. • *Controlling the Strip* (2003-2006) focused on soil health, minimum tillage & irrigation efficiency. *Advanced Farming Systems* (2008-2009) investigated farmers' engagement with advanced Precision Agriculture technology.

Table 2: Characteristics of farming groups / sectors

Farming Group	Farming group / Sector characteristics
Crop Science for Māori East Coast Organic Producers (ECOP)	• East Cape Region: Economically deprived and geographically isolated. • ECOP Trust sought to improve the health, social, cultural, economic and ecological wellbeing on the East Cape by promoting cultural values. • ECOP Trust membership was very small – approximately 6-10 growers. • Community had limited understanding of science as a development tool. • Boundaries of influence limit knowledge sharing between communities. • Communally owned land makes development capital hard to secure.
Squash Rot Squash Industry group	• Group funded by grower levy, supported full time employee. • Product group of grower body (Horticulture NZ) with strong policy focus. • Complex industry value chain. • 5-6 corporate growers largely control the squash value chain. • Competitive industry players; price sensitive market.
Potato Aphid Project Potatoes NZ	• Group funded by grower levy, supported full time employee. • Product group of grower body (Horticulture NZ) with strong policy focus. • Complex, competitive value chain with three sectors: seed, process, table. • In the seed sector (where the project was targeted) profit margins are small. • Seed potatoes are rarely grown as a sole crop. • Most farmers contract grow for seed potato merchants.
Walnut Blight Project Walnut industry Group (WIG)	• Small emerging industry progressing towards commercial production. • Consists largely of part-time growers, many are scientists and other highly skilled professionals along with older retired couples. • Industry group formed by farmers to represent growers & access funding. • Voluntary membership, so dependent on grant success for group's knowledge generation – no paid staff. • Long association with Lincoln University and access to trial orchard.
The Wheat Calculator Foundation for Arable	• FAR funded by grower levy, supported several full time employees. • FAR supports research and technology transfer in the arable sector. • Facilities located next to major science institutes. • Complex value chain with multiple industry players. • Majority of growers are contract growers & often engaged in mixed cropping.

Research (FAR)	• Farmers' incomes are influenced by the international grain price.
Precision Agriculture LandWISE	• LandWISE is an established and respected farmer extension group focusing on Precision Agriculture. • Voluntary membership - supported 1-2 part time staff. • Primary income from research grants; vulnerable to funding changes. • Partners with complementary organisations including research institutes. • Scientist sits on the LandWISE Board. • Collegial cooperative membership.

4. Methodology

The research used a case study approach (Yin, 2009) to gather empirical evidence from the six projects to explore how participatory research in micro-level agricultural projects created learning environments. Multiple sources of evidence were gathered from 84 stakeholder interviews, which were recorded and transcribed, eight participant observations and a review of project documentation and media articles. Interview participants included project actors including farmers, research scientists and farming group employees. In addition interviews were undertaken with actors from the wider agricultural innovation system.

Four of the projects had finished and so were examined retrospectively, and two projects were examined while in progress. A large and rich corpus of data was collected and analysed to code, order and structure the data. Two "cycles" of coding were applied guided by Saldana's (2013) approach to analytical coding. In the first cycle, "holistic coding" (Saldana, 2013:142) was undertaken as a "grand tour" to gain a first impression of the data corpus. This was followed by in-depth second cycle coding which led to 20 coding categories being identified. These grouped into three themes: the institutional context for innovation; partnerships; and learning. This paper focuses on the 'learning' theme.

5. Results

An examination of how knowledge production occurred in each project revealed how projects fostered a discursive learning space for actors to engage, share, collaborate and co-develop. When the six projects were viewed through this knowledge production lens, they could be divided into three groups as discussed in section 5.1-5.3 below.

5.1 Linear Knowledge Production (scientist-initiated)

Although all projects employed a participatory methodology, linear processes were evident in two projects - the Potato Aphid and Squash Rot projects. Interestingly, both were scientist-initiated and farming actors were principally observers of the project's research, rather than active research participants. Project steering committees managed both projects and farming actors largely ensured that the field research undertaken by the scientists, aligned with farming operations. With minimal farmer engagement in fieldwork and a primary focus on data collection to answer 'science' questions, the development of a collaborative learning space was limited.

The empirical evidence from the Squash Rot and Potato Aphid projects showed that when farmers are largely isolated from the fieldwork, a project is unable to foster a meaningful discursive space where partners can share, communicate, negotiate and build trust, to learn together and co-develop innovations. Project committees allowed partner input, but interactions typically focused on operational matters. While this may be useful for aligning operational and research components, it does not foster active engagement in a 'learning by doing' approach that is integral to effective participatory research (Douthwaite et al., 2003). The linear approach to knowledge production in these projects largely reflects the Transfer of Technology (TOT) approach to research and extension.

5.2 Collaborative Knowledge Production (Farming-group initiated)

In the Walnut and Precision Agriculture projects, farmers and scientists collaboratively engaged. Both projects were established on partnerships initiated by the farming groups. Farmers in these groups (some of who were scientists) drew on both explicit codified and tacit knowledge to address issues. They valued science input and sought engagement with particular specialists, however they sought outcomes relevant to their farming business and expected this relevance to be evident in the project design. To maintain relevance, field trials were managed by the farming group.

LandWISE and WIG saw themselves as innovators. The groups employed a 'learning by doing' approach and they actively facilitated field gatherings with members, sometimes only involving scientists as advisors or analysts of data collected by farmers. These small self-organised discursive spaces enabled farmers to share and co-produce knowledge. However, they drew on scientific expertise as needed to more deeply understand the complexities of the systems in which they farmed. They saw the science / farmer relationship as a synergy between what Ingram (2008) calls the know-*how* of the farmer and the know-*why* of the scientist.

While WIG and LandWISE maintained positive long-term relationships with scientists, they created a new power dynamic that directly challenged traditional linear approaches to research and extension. Despite positive partner relationships this new power dynamic challenged scientists' desire for a robust and rigorous methodology to agricultural investigations. As a result, research in collaborative spaces led by these farming groups, blurred traditional agricultural research boundaries.

5.3 Negotiated Knowledge Production (joint scientist and farming group initiated)

Negotiated learning spaces, where partners jostled for position occurred where partners needed to become familiar with each other's expectations before they could effectively collaborate. This occurred in the Crop Science for Maori and Wheat Calculator projects, which were jointly initiated by farming and science actors. Partners needed to establish a foundation of trust on which to build a learning space. For effective dialogue to occur, relationships needed to firstly be humanised (Yankelovich, 1999). This was most notable in the Crop Science for Maori project which operated in remote Maori communities. Here scientists needed to respect, learn and understand how to operate in a community with strong cultural values and limited understanding of science as a development tool. This required scientists to temper personal and organisational expectations about project timeframes and create greater flexibility in project delivery.

In the Crop Science for Maori project the positive relationships which developed over time, provided the enabling factors for collaborative learning that sought to incorporate both *Mātauranga Māori* (Māori knowledge) and western science knowledge into project learning. The community wanted science knowledge to complement not replace their traditional knowledge. Only when trust was established could learning extend beyond a singular focus on kumara (Maori potato) crop production into issues such as market access which led to workshops where chefs provided tastings of specialty kumara dishes and scientists worked with the community to organise two food festivals to showcase their organic produce.

In the more conventional partnership of the Wheat Calculator project, science and farming actors were familiar with engaging and farming actors had more understanding of science. Trust building was however, still required to overcome an early misalignment of partner priorities that led to a power struggle between partners. This exhibited as a clash between the scientists' requirement for evidence-based findings that valued outputs that were robust and statistically rigorous, and the lived experience of farmers who sought knowledge that was relevant to farming practice. To become an effective learning space, actors needed to understand each other and to collaboratively create a shared vision.

6. Discussion

The examination of how knowledge was produced in the projects revealed that learning spaces were created most effectively in projects that fostered collaboration and where knowledge was co-produced. This environment created a 'collaborative learning space'. Section 6.1 explores project characteristics that impeded or fostered a collaborative learning space, while Section 6.2 visualises how effectively the learning in the projects advanced sustainability.

6.1 Creating a 'Collaborative Learning Space'

The creation of a collaborative learning space is essential for fostering knowledge co-production that drives innovation and change. Knowledge co-production is created when collaboration, trust-building and negotiation between partners is fostered in this supportive learning space. Without active collaboration in projects, linear knowledge production occurs. Trust building is critical where relationships need to overcome initial power differentials and struggles as collaborative learning challenges institutions that attempt to maintain existing power relationships.

Boundary crossers, who connect actors from different sectors (Veitch, Taylor, Kilpatrick, Farmer, & Chesters, 2007) were often used to unlock the learning space. Farming groups who had a strong research focus, (LandWISE, WIG and FAR), took on this critical 'connection' role between science and farming actors and also fostered farmer to farmer learning. Their open and collegial cultures and structural arrangements supported collaborative engagement.

The empirical evidence revealed characteristics that impede and foster a collaborative learning space. Table 3 outlines the characteristics that impede collaborative learning while Table 4 outlines those that fostered the development of a collaborative learning space.

Table 3: Project characteristics that impeded collaborative learning spaces

Characteristic	Examples of empirical support from research
Primary focus on science / crop research not learning processes	Squash project focused on fieldwork for scientists to be able to develop a rot predictor tool. Potato Aphid project focused on gathering field data for scientists to develop a resistance management strategy. Crop Science for Maori project focused on 'kumara' production, which under-estimated market requirements and led to a huge quantity of large sized kumara that the market did not value.

Scientifically complicated research ‘shoe-horned’ into participatory projects	Squash Rot project fieldwork was technically complicated and so provided few opportunities for collaboration.
Segmented roles for actors – Scientists responsible for the research while farmers take a passive role in project research	In the Squash and Potato Aphid projects scientists undertook the fieldwork. Farmers’ input was confined to project logistics to ensure science fieldwork aligned with farming operation.
Only formal arrangements for collaboration	In the Squash Rot and Potato Aphid projects, steering committees provided the primary site for partner engagement and discussion in the project.
Didactic teaching methods employed	In the Crop Science for Māori project scientists began with classroom-based teaching. The community resisted this ‘teaching’ approach to engagement.
Project knowledge production does not align with farming practice	The Wheat Calculator software initially did not reflect the way farmers managed their crop.
Organisational infrastructure does not support innovation	Information from field trials assessing aphid numbers was too slowly uploaded to the Potato Aphid project website. Potato Aphid’s ‘bowl traps’ presented problems for farmers’ aphid identification. Weather stations in the Crop Science for Māori project were technically cumbersome or inappropriate. Geographical isolation of the East Cape impeded regular collaboration between actors due to distance to field sites.
Institutions are not supportive of collaborative innovation and co-production	Industry / community institutional cultures in Potato Aphid, Squash Rot and Crop Science for Māori projects limited collaboration among community participants e.g limited sphere of influence across Maori communities. Scientists’ perception of farmers as receivers of science knowledge (challenged by farming group in the Wheat Calculator project)

Table 4: Project characteristics that fostered collaborative learning spaces

Characteristic	Examples of empirical support from research
Learning by doing approach	Farmer experimentation played a significant part in farmers’ understanding of their environment e.g LandWISE, and WIG farmers actively engaged in field experimentation; WIG’s benchmarking orchard work set protocols for blight management. LandWISE’s farmer-led trials allowed farmers to manage soil quality and to adapt and apply the learning to their farm conditions.
Co-development of innovation through learning by interacting	Active engagement with scientists to share knowledge: WIG and LandWISE contracted scientists to engage in

and/or learning by using (Hekkert et al., 2007)	field activities with farmers or advise on farmers' trials. In the Crop Science for Māori project, growers and scientists co-developed knowledge so science knowledge complemented not replaced their traditional / local knowledge e.g the production of a kumara growing calendar showed how local and science knowledge could be integrated into project learning and outputs.
Trust-building / Relationship-building	Trust is essential for collaboration, especially where projects had to overcome power difficulties and differing worldviews (Wheat Calculator and Crop Science for Māori).
Functioning peer learning networks	LandWISE and WIG created explicit learning networks of farmers actively engaged in the project research, their communities of practice, scientists and relevant industry players.
'Science' is valued by farmers as a development tool and is embodied in project learning.	Research-focused groups (FAR, LandWISE & WIG) understood science as a development tool and science methodology. LandWISE farmers referred to science first principles. WIG's research committee sought 'evidence-based' research to develop orchard best practice of spraying regimes. For these groups farmer / scientist relationships were positive learning relationships where partners developed respect and shared understandings. FAR, LandWISE and WIG all had research committees.
Local knowledge (gained from farming experience or cultural knowledge) is valued by scientists and embodied in project learning.	Collaborative learning challenges linear approaches to research. Many of the difficulties that do arise from challenging how scientists might view themselves professionally and personally are overcome through maintaining positive relationships between science and farming participants
Institutional frameworks that support innovation	FAR had both capacity and capability to support innovation, including staff, secure finances, organisational structure, infrastructure. WIG and LandWISE had capability to support innovation but their dependency on grants made them vulnerable to changes in funding regimes. All these groups fostered innovation through their formal and informal institutions.

6.2 Visualising collaborative learning for sustainability

To visualise and compare how effectively the six projects fostered learning spaces to address agricultural sustainability, a number of important characteristics with the potential to enable collaborative learning for sustainability were identified from the empirical evidence. These were tabulated to allow each characteristic to be compared across projects and each project to be compared across characteristics.

Each characteristic was qualitatively ranked for each project, as enabling learning (green); disabling learning (red) or being indifferent (orange). Figure 2 visually presents the characteristic ranks for each project. To increase the discrimination for each characteristic, cells of mixed colours indicate a project characteristic that was heterogeneous, to reflect variable actor responses for that characteristic.

Columns have been arranged across the figure in descending order of projects that enable learning. Rows were then similarly ordered in descending order of learning enablement across the six projects. This ordering concentrated those projects and characteristics with the greatest learning enablement in the top left corner of the figure, and those with the greatest learning constraints in the bottom right of the figure.

It can be seen that following the rearrangement of the table as described, the projects have grouped into a 2 x 2 x 2 pattern which coincides both with the groupings of who initiated the project, and also the type of learning space (linear, collaborative or negotiated) that was created. Farming group-initiated projects, which created collaborative knowledge production had the greatest degree of learning enablement followed by shared partnerships (negotiated knowledge production) where learning enablement was heterogeneous across almost every characteristic and science-initiated projects which largely disabled collaborative learning. Within the science-initiated projects a few characteristics were heterogeneous but none fully enabled collaborative learning.

Comparing these characteristics across the investigated projects provides insight into the effectiveness of individual projects and of projects collectively in realising and most importantly optimising learning for sustainability in the collaborative learning space. Of particular importance in Figure 2 are the learning attributes that contain characteristics that should be evident in innovation projects addressing agricultural sustainability. Co-development and trans-disciplinarity indicate evidence of an enabling learning environment for innovation (Curry, Ingram, & Maye, 2012; Wieczorek & Hekkert, 2012). Temporal and spatial dimensions recognise the need for innovations to address long-term issues and recognise differing scales. The longevity of project learning has also been explored to see if the outcomes from collaborative learning are sustained in farming communities beyond the funded period of a project, a characteristic argued to be important in sustainability projects and usually indicative of institutional capacity building at the local level (Pretty, 1995). The comparative analysis of the six projects shows the collaborative learning space to be highly variable.

FIGURE 2 HERE

7. Conclusion

This research shows that actor engagement and learning to address sustainability is a complex social process. As a result the creation of a 'collaborative learning space' in micro-level agricultural projects is highly variable. The development of this learning space is critical as the complexities of sustainability will necessarily require integrating different perspectives and knowledges to facilitate questioning of the assumptions and values that drive current practice.

Where changes to agricultural practices are sought as an outcome, actors need to actively engage in a collaborative learning space. In this research this collaboration most effectively occurred in informal peer networks where participants collaboratively engaged in a discursive learning space. Such transdisciplinary environments acknowledge the constructed nature of agricultural knowledge.

When participatory projects create opportunities for multiple stakeholders to collaboratively learn, issues can become apparent, negotiated and resolved. Reframing current understanding of participatory research and conceptualising it as a collaborative learning space provides the opportunity for knowledge to be co-developed where learning can be emergent, adaptive and dynamic.

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Figure 2: Visualising project realisation of learning for sustainability