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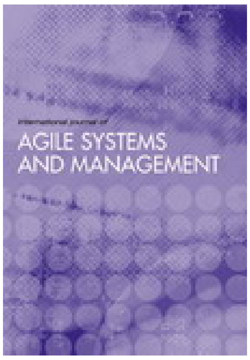

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Choosing the wrong integrated research approach and how to correct it: reflections on developing a shared information management system

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Choosing the wrong integrated research approach and how to correct it: reflections on developing a shared information management system

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Abstract: Researchers often lack critical information to decide what type of integrated research approach – multi-, inter- or transdisciplinary – is needed at the start of a project. In the present paper, we aim to contribute insights regarding these difficulties by discussing the case study of the ongoing development of shared information management systems (SIMSs). SIMSs form the backbone of state-of-the-art transparency schemes called 'hyper-transparency' schemes. Such schemes offer small businesses the opportunity to establish more direct relationships with consumers and citizens. Developing a SIMS is complex, requiring collaboration between many different disciplines and practitioners. We discuss how our approach has evolved during the development process from a multidisciplinary towards a transdisciplinary approach. We outline the challenges that arise at the start of a project when the chosen approach does not match well with the research problem at hand. We discuss how we are planning to overcome these challenges. The case study presented here is relatively novel in the literature and thus should act as a valuable resource as the importance of integrated research grows.

Keywords: integrated research; transdisciplinary; shared information management system; transparency; hyper-transparency; supply chain redesign.

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1 Introduction

The concept of 'integrated research' refers to all 'beyond disciplinary' approaches (Stock and Burton, 2011). That is, all approaches that deal with problems that cannot be addressed through a single science discipline and that attempt to link, integrate or fuse knowledge from multiple disciplines (including non-sciences ones, when necessary) (Lawrence and Després, 2004).[1] Three main types of integrated research can be distinguished, ranked here in order from low- to high-degree of "integration": multi-, inter-, and transdisciplinary.

Multidisciplinary research involves projects where a problem (e.g., the competitive position of the European pork meat industry) is addressed from different angles or disciplines (e.g., economists, meat scientists). In a multidisciplinary project, researchers mostly address the problem from their own disciplinary perspective (Lawrence and Després, 2004). For example, an economist may study the transaction costs that agribusinesses in European countries incur when compared to key non-European competitors, while a meat scientist may do a cross-country study of pork meat quality. While researchers may share and exchange results throughout the life of a multidisciplinary project, integration of knowledge takes place mainly in the reporting phase and then only to a limited degree (Stock and Burton, 2011).

Interdisciplinary research refers to projects where collaborative learning across different science disciplines is necessary to address the problem (Scholz and Steiner, 2015c). Here, integration of knowledge takes place systematically, across all stages of the research project. Researchers from different disciplines have to jointly frame the problem and decide together on what the appropriate methods and tools are for finding solutions based on insights derived from each of the disciplines (Stock and Burton, 2011). For example, to study the environmental footprint of pork meat supply chains, life-cycle assessment scientists, supply chain researchers, and process engineers, will have to build on, learn from, and integrate each other's knowledge and insights to co-develop a methodology that captures all of the natural resources that are used and wasted at the different stages of the supply chain (and in-between).

Transdisciplinary (TD) research integrates knowledge from a wider range of different types of stakeholders, including from scientists from a diverse set of disciplines (both from the natural and as well as from the social sciences (Peruzzini and Wognum, 2019)) but also specifically from non-scientists, such as industry actors, municipalities, citizens, etc. (Newnes et al., 2020; Wognum et al., 2017, 2019; Scholz and Steiner, 2015a). As such, it can be viewed as a fusion of interdisciplinary research with multi-stakeholder discourse (Scholz and Steiner, 2015b; Lauto and Sengoku, 2015). However, TD research has broader objectives and deals with more complex problems than interdisciplinary research.

Whereas the creation of new, integrated knowledge to address a well-defined science problem is the objective of interdisciplinary research (e.g., how to best measure the environmental footprint of a supply chain), TD research tends to deal with ill-defined problems that have an explicitly normative component (Scholz and Steiner, 2015a). In the European pork meat industry example, the ill-defined problem is how to transform it so that it remains competitive and keeps its social license to produce. Such problems arise in complex systems, with many different actors with competing interests (Wognum et al., 2017). The desired end-state of a complex system is unclear, subjective, and furthermore continuously changing because these systems are dynamic.

Because of this, the objectives of TD research are broader than enabling stakeholders to deal with a specific situation or problem, as constantly new problems arise, and the parameters of existing problems are constantly changing. This broader objective is to empower stakeholders to deal with different types of future problems or scenarios collectively, beyond the life of the research project, by enhancing their ability for mutual learning and joint-decision making (Scholz and Steiner, 2015a; Schauppenlehner-Kloyber and Penker, 2015).

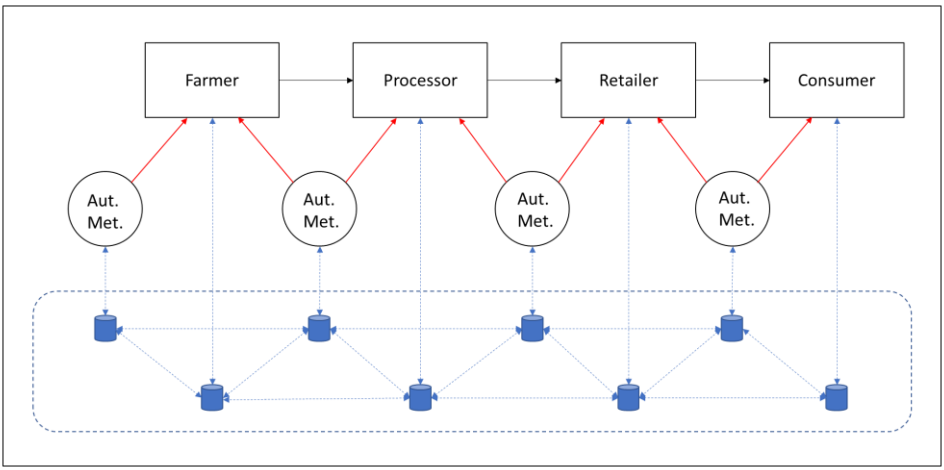
Researchers often lack critical information to decide which type of integrated research approach – multi-, inter- or transdisciplinary – is needed at the start of a project. In the present paper, we aim to contribute to insights into the difficulties researchers face when setting-up integrated research projects under such conditions. We do this using the ongoing development of a shared information management systems (SIMSs), which some of the authors are leading, as a case study. We reflect on the challenges we faced starting with an inappropriate approach and discuss what steps we are taking to address them including how our approach evolved from a multidisciplinary towards a transdisciplinary one.

The remainder of the paper is organised as follows. In Section 2, we briefly describe the general purpose and functioning of SIMSs, which is to enable more transparency in supply chains through a combination of digital technologies. We explain the difficulties and uncertainty researchers face in making decisions about what research approaches to use for such complex projects. In Section 3, we give a short overview of the SIMS we are developing and describe its various components. Section 4 discusses the SIMS's development process, the integrated approach we started out with, and the challenges we faced as a result. Section 5 outlines the steps we have taken to implement a transdisciplinary approach in order to address these challenges. Section 6 identifies avenues for further research and highlights potential lessons of the study for the management of integrated research projects. Section 7 concludes the paper.

2 Transparency schemes, SIMS, and the difficulty of choosing an integrated research approach

Transparency schemes in agri-food supply chains communicate information about food products and production practices to consumers, citizens, and other stakeholders (Wognum et al., 2011; Trienekens et al., 2012; Pena et al., 2010). Recently, 'hyper-transparency' schemes have emerged that enable stakeholders to verify some food claims themselves. This change is facilitated by advancements in digital technologies which have made it possible to develop SIMS (Francisco and Swanson, 2018; Galvez et al., 2018). SIMSs connect farmers, agribusiness and other actors operating in agri-food supply chains (please see Figure 1 for an example of a SIMS). Through such platforms, as well as a combination of novel sensor technology (e.g., IoT-devices) and cryptography, supply chain actors can give their trading partners, as well as consumers and citizens, real-time insight into the origin, attributes and production circumstances of the inputs or end-product that they are buying. SIMSs offer farmers and agribusinesses the opportunity to establish more direct relationships with consumers and citizens.

Figure 1 Schematic diagram of a shared information management system (see online version for colours)



Uninterrupted black lines: product flows; uninterrupted red lines: monitoring activity; interrupted blue lines: information flows; the blue cylinders represent connected databases; Auto Met.: Automated metering.

However, developing a SIMS is a challenging task. It requires collaboration between several different disciplines from both practice and academia. Within academia, preferably both technical and social science expertise is required. Identifying user interface needs and to anticipate the longer-term impact on the user community and society draws upon social science and user experience disciplines. Domain and technical knowledge consider the context in which the system needs to function across the supply chain.

SIMS development thus requires some form of integrated research approach, but the appropriate choice of approach can be dependent on the answer to several unanswered questions at the outset of a project.

- Is a mix sufficient (an interdisciplinary approach) or would a fusion of disciplines be more suitable (a transdisciplinary approach) (Lawrence and Després, 2004)?

For example, key aspects about a project, such as the amount of cooperative learning or stakeholder involvement required, may be missing. This raises three further questions:

- How can the answer be discerned at the start of a project when researchers may lack critical information?
- What are the implications of choosing a ‘wrong’ approach?
- To what extent can such an occurrence be addressed when a project is already significantly advanced?

It is within this uncertain context that many complex projects, including the case study described in this paper, start out with.

3 The SIMS in question

The SIMS discussed in this paper is being developed for New Zealand agri-food supply chains to help farmers and other smallholders in the country create hyper-transparency schemes. A SIMS can support smallholders by significantly lowering the time and costs of keeping track of the origin of food products along the supply chain. This could enable more smallholders to set up their own supply chains and market their products as differentiated goods to consumers. We consider the purpose of the SIMS in both narrow and broad terms. The SIMS’s narrow purpose is to help farmers improve their market access, as well as to give consumers more comprehensive and unfiltered access to information about the way their food is made.

The broader purpose is to enable mutual understanding between farmers and citizens to aid farmers in maintaining their ‘social licence’ to produce. As in many countries, environmental and animal welfare concerns amongst citizens in tandem with a general disconnect between farmers and citizens has emerged in New Zealand. Unusually though in New Zealand, this has led to a significant discussion regarding farmers needing to earn their ‘social licence’ to continue operating (Hampton et al., 2020; Benard and de Cock Buning, 2013; Piddock, 2018). The SIMS could help forward-looking and open-minded farmers and citizens to address this disconnect. How? The system will include communication tools that give the two parties the means to establish closer connections and a platform for improving mutual understanding. In this way, usage of the SIMS by these stakeholders could enable them to increase their capacity for addressing the agri-food sectors’ challenges collectively.

The envisioned SIMS is made-up of five sub-components:

1. an infrastructure module supporting the other four elements
2. a farm module
3. a post-farm gate module
4. a consumer module
5. a communication module.

Table 1 gives a detailed description of each of the modules.

Table 1 Description of the SIMS's modules

Infrastructure module
The infrastructure module is a cloud-based online platform. Data from the farms and other components of the supply chain are directly and continuously collected via IoT devices and transferred to the data warehouse or data lake managed in the shared system in the cloud. There are two components to this platform. First, the data management system is designed using the schematic shown in Figure 1, where the individual databases of the parties participating in the transparency scheme run are connected. Second, an automated data processing algorithm is implemented to check the quality of data and convert data into desired formats. Data governance, security protocols and proper access control for all actors in the supply chain are implemented here
Farm-level module
The farm-level module refers to the sub-system through which data is collected at the farm. Mostly, this will be done via sensors and IoT enabled devices, that automatically collect farm-level data (e.g., environmental data, data about animal behaviour, etc.) and upload it to the cloud. For example, we are planning to use GNSS positioning sensors on cows, enabled with LoRA wireless technology, to track and record the activities of the animals and benchmark these data against indicators of animal health. We also intend to use WIFI-enabled cameras with motion detectors that can track the animals around the farm to provide a visual indication of how the animals are doing
Post farm gate module
In the post-farm gate module, we aim to deal with the problem of gathering and integrating verifiable information into the SIMS about agricultural 'inputs' or 'products' after they have left the farm gate. In many agri-food supply chains this can be challenging. For example, it is often difficult to keep track of products at the processing stage of the supply chain (Wognum et al., 2011). At this stage, 'inputs' from different types of farm often get mixed and it can be prohibitively costly for the processor to keep product flows from different types of farm separated. Technological advances, however, give companies in the supply chain a couple of options around this problem. Firstly, technologies are being developed in some agri-food supply chains that allow farmers to undertake processing activities by themselves (e.g., such as on-farm dairy processing). Subsequently, the farmer can sell their products directly to the consumer. Secondly, novel measurement and sensor technology have been developed that, when linked to a SIMS, help to significantly reduce the time and costs of: (a), keeping track of the origin of food products (e.g., DNA based-tracing of meat products); or (b), providing verifiable information about product attributes that can link measurements at the processing stage of the supply chain back to the type of farming system under which the products have been produced. An example of the latter type of solution is being developed within the larger program of which this project forms part (see Section 4.1). More specifically, a methodology is being developed to trace molecular signatures of milk at the farm and factory gate. These signatures give an indication of the type of farming system (e.g., type of feed) under which the milk is produced. Our SIMS will be linked to this methodology
Consumer module
Through the consumer module, buyers of food products can get direct insight into how their products are made. Here, the main concerns are: (1), how to make the process of getting access as easy as possible for consumers; (2), how can we stimulate them to actually engage with the platform. To deal with the first challenge, we will be using QR-codes, whereby consumers scan a code on the packaging of the food product with their phone and then visit the farmer's website. To deal with the second challenge, we have analysed existing websites in the food-transparency space and have undertaken a consumer survey (see also Section 4.2). Our analysis suggest that gains can be made in the following areas vis-à-vis existing hyper-transparency schemes: 'personalising' information (e.g., by showing information about individual animals), using more audio-visual information (e.g., through live video-feeds of the farm), by presenting such information in an engaging fashion (e.g., we intend to track animals around the farm through cameras with motion-detection sensors), and by presenting 'numerical' data in a 'visual' manner

Table 1 Description of the SIMS's modules (continued)

Communication module
We envision a communication module where consumers can ask questions to the farmers in real-time about farming activities. This will allow both parties to not only engage but to also clarify potential misunderstandings. Farmers are generally busy people and it is hard for them to spare time to communicate with consumers. Realising this, we propose an Artificial Intelligence-based (AI) control system. The AI control system is equipped with text-to-voice, voice-to-text and Natural Language Processing technologies. Consumers can ask question in both voice and as written text; this will be received by the AI control system. This system will process the content in real-time to check for any abusive behaviour and provide immediate responses to previously answered questions. Novel questions will be delivered to the farmers as audio or text, and can answered by voice or text. Subsequently, the AI control system transfers the answer back to the consumer

4 Development process, challenges, and the need for a transdisciplinary approach

In this section, we describe the SIMS project context (Section 4.1), the disciplines involved (Section 4.1), and the ongoing development process (Section 4.2). We explain that we started the project using a multidisciplinary approach. However, this led to various challenges, as discussed in the Section 4.3 which highlighted the need for a transdisciplinary approach.

4.1 Background to project

The SIMS-project is part of a larger research program, "New Zealand Bioeconomy in the Digital Age" (NZBIDA). This is a multi-million-dollar program undertaken by AgResearch, which is one of the country's seven Crown Research Institutes (CRIs).[2] NZBIDA aims to help the agri-food sector better leverage digitalisation opportunities to aid becoming more sustainable and resilient. The relevant NZBIDA workstream studies consumer and societal confidence in farmer production practices. A particular focus is if and how confidence can be restored and enhanced through clearer product provenance facilitated by novel data collection and sharing technologies. Across the NZBIDA program about 70 people participate, from a wide range of disciplines such as soil scientists, farm management researchers, life cycle scientists, anthropologists, meat scientists and modellers.

Designing a SIMS requires expertise in a range of disciplines such as data science, robotics, communication science, supply chain management, engineering, sensor technology, and economics. With that in mind, the core team developing the SIMS was selected based on both the depth and breadth of their knowledge. The core team consists of three people, all of which have a T-shaped skill set, with depth in expertise in at least two of the above-mentioned areas, together with a broad set of interests in other areas. Illustrating this T-shaped skill set, one held a PhD in the area of supply chain management and economics, a master's degree in communication science and had experience in market research about online dashboards.

The core team is directly responsible for development of four out of the SIMS's five modules. The exception is the "post-farm gate module". Here the "food authentication" team (part of the same workstream within the NZBIDA program) develops methods for gathering verifiable information about product attributes at the processor stage of the supply chain. One member of this team is the budget manager of both the SIMS team and the food authentication team and acts as a liaison to promote collaboration and exchange of ideas.

4.2 Development process

At the outset of the SIMS project, a specific integrated approach was not chosen. We were experienced collaborating with other disciplines. Therefore, it was not difficult, for example, to find common concepts and language through which we could efficiently communicate with each other. While each member had to educate themself in certain areas, each had prior experience in doing so. We thus did not feel the need to set-up a structured approach to collaborating.

There were some challenges in collaborating with several of the other workstreams in the NZBIDA program. The capabilities of AgResearch have traditionally been in the natural sciences (e.g., soil science, material sciences, genomics) and some of the capabilities that are required to develop the SIMS (e.g., supply chain management, economics, data science) are relatively new to the organisation. This made communication with researchers from the wider program sometimes difficult. However, this was viewed as a long-term organisational-level issue that was beyond the scope of the SIMS project to address.

In retrospect, the integrated approach of the SIMS team can best be described as falling somewhere in between multidisciplinary and interdisciplinary collaboration. We crossed over into each other's domains, but only to a certain degree, and only where it was required in order to solve problems that were directly related to the design of the SIMS. While working well together, each of the members also worked in a largely self-contained manner and we did not systematically synthesise or integrate knowledge from the different science disciplines as is considered a key component of interdisciplinary collaboration. Our approach also fell well short of TD collaboration. As is further discussed in Section 4.3, we only interacted with industry stakeholders, such as farmers, sporadically. Therefore, the opportunities for collaborative learning between scientist and practitioners were limited.

In terms of staging of the design process, we roughly followed the five-stage approach associated with Stanford's Hasso Plattner Institute of Design: empathise, define, ideate, prototype and test (Jensen et al., 2016). The seed of the idea for the project originated from the experiences the leader of the SIMS team had in prior research projects involving stakeholders from the agri-food sector. In these projects key challenges for the agri-food sector included its legitimacy, farmers' social license to produce, and animal welfare concerns. The disconnect between the agri-food sector and citizens, consumers and other industries was identified as a key barrier to solving many of these challenges.

The question of how to address these issues was discussed with other NZBIDA researchers in the initial stages of the program. These discussions led to the idea for an online dashboard as a channel that could help establish closer connections between farmers and consumers/citizens. This idea was contrasted with other potential solutions, both in meetings within the project's own workstream as well as in workshops within the wider program. After the 'dashboard' idea was selected, broad objectives, strategy, plan, budget, and team for the project were established in consultation with the workstream's leader, as well as with the NZBIDA program manager.

Through brainstorming sessions, the team developed several concept versions of the dashboard. These concept dashboards were tested through largely informal discussions with farmers and industry experts. Furthermore, during these discussions, the project team elaborated on the dashboard idea to propose a more coherent solution: a SIMS. Subsequently, working prototypes of the dashboards were created in Microsoft Power BI (an online dashboarding tool). These prototypes had limited functionality and were based on synthetic data. Users could interact with the dashboards online, but the dashboards were not connected to working IoT devices on a farm. Again, these were tested in informal discussions with farmers and industry experts. Finally, consumer interest and willingness to pay (WTP) for hyper-transparency was tested through the earlier mentioned survey (of 300 respondents). The survey also gauged consumer attitudes towards specific components of the proposed dashboards, as well as their information needs (e.g., at what level of granularity should information be presented: farm-level hyper-transparency or animal-level hyper-transparency).

4.3 Challenges

During the above-mentioned process we encountered three main challenges that impressed upon us the need for a TD approach:

1 while there was a significant interest from stakeholders in the proposed solution, there was also a low willingness to contribute towards realising it

2 stakeholder knowledge was integrated in the development process only to a limited degree, as previously touched upon

3 we drifted away from the problem we were originally trying to solve, which raised questions about what publicly funded research is best placed to do relative to the free market.

With regard to the first issue, stakeholders were consulted on an ad-hoc basis and were not involved as partners to the project. This meant that stakeholders did not have a direct stake in the project's success, even if they would (hopefully) stand to gain from any success that the project would help realise. This reduced their willingness to contribute their time to it, which in turn made stakeholder involvement more cumbersome for the researchers, who had to spend their time chasing contacts and convincing them to give feedback. It also meant that we did not develop the close connections required to engage in collaborative learning over the course of the project. Collaborative learning helps both sets of actors better understand how each of them works and thinks. This improves the discourse between researchers and stakeholders and increases their capacity for future collaboration. However, it requires that both "parties move beyond their immediate wants (the need for feedback on a proposed solution from a researcher's perspective, and the need for tailor-made solution from the perspective of the stakeholder) (Scholz and Steiner, 2015a). To learn from each other requires time and effort from both parties. Stakeholders are unlikely to make such commitment if they are not treated as a partner to the project.

With regard to the second issue, and partially related to the previous point, knowledge from stakeholders was not systematically integrated into the design process. While we developed structured and semi-structured techniques for gathering insights from stakeholders (e.g., a survey for consumers, a topic list for farmers), we did not employ a structured approach to using those insights for building a 'better' solution. Rather, we relied mainly on our intuition to adapt and learn from these insights. As a result, some of the insights that we gathered from stakeholders were 'lost' in the process of translating those insights into actionable design parameters and tasks.

With regard to the third issue, we started the project by trying to address a rather complex problem, which involved a large set of stakeholders: how to enable and empower smallholders from the agri-food sector to establish closer connections with the remainder of society in order to help them maintain their license to produce.

Over the course of the project, however, we drifted towards a narrower problem: how to create and develop a SIMS for entrepreneurial farmers to help them better market their products to consumers. While it is normally a good thing to develop a more specific focus over the course of a project, in this case it fundamentally altered the nature of the project. The more 'product-oriented' focus of the project raised the issue of whether we as researchers should undertake this project, or whether this type of endeavour was better undertaken by more commercially focused private companies and consultants (see also (Scholz and Steiner, 2015a)).

5 Towards a transdisciplinary approach

In this section, we first discuss some of the key steps we are taking toward applying a TD approach to the development of the SIMS and toward addressing the challenges discussed in the previous section. Subsequently, we discuss the challenge of maintaining an open discourse while applying a TD approach.

5.1 Key steps

To what extent is it possible to implement a TD approach in a project that is already well underway? The key challenge here is that we want to build as much as possible on the work that we have already done, rather than start from scratch. As design and development are iterative processes, we believe we can still change our approach and not discard all previous work and findings. At present, we have completed a single loop of the SIMS's development phase, with the main outputs being a conceptual design of the SIMS and a prototype with limited functionality. The second loop of the development process – where we will re-assess the project's objectives and the SIMS's conceptual design, and intend to develop and test a fully functioning prototype – will be specifically informed by a TD approach. During this second loop we will review the objectives, findings and assumptions made during the first loop to compensate for the lack of a TD approach during the first loop.

To help realise this TD approach we will use the following three additional actions. The first action is already in motion where we have been consulting with an external expert in the area of TD design and engineering.

The second action is to improve stakeholder engagement to ensure that stakeholders have a stake in the project's success going forward (see Polk, 2015). For example, we will work closely with a farming family to co-design and co-develop the SIMS. Amongst others, a prototype of the SIMS will be implemented at their farm. The family will be asked to contribute to the cost of implementing the IoT devices that link to the SIMS. This will act as both an incentive (subsidised equipment) and commitment (remaining cost paid by the farm family) to contributing to the project's success using the technology.

Furthermore, we will also include citizens in the project, especially those that are directly affected by agricultural producers. This could include those that live close by farms, or live close by waterways polluted by agricultural activity who will have a strong incentive to contribute to solutions that lead to a more sustainable agri-food sector. The key challenge here will be to include a diverse set of citizens, while ensuring that most of them are open to engaging with the farming community in a constructive way to devise solutions to deal with harmful social or environmental effects of farming. Reflexive Interactive Design, an approach to help stakeholders address complex trade-offs in sustainability contexts through deliberation and reflection, could be useful to help ensure such constructive engagement (Romera et al., 2020; Bos et al., 2009).

Higher stakeholder engagement, from a more diverse set of stakeholders will help us reassess the projects objectives. Questions that will have to be jointly addressed with stakeholders include:

- Will the SIMS be a valuable tool to help farmers market their product and for consumers to verify product provenance (the SIMS's narrow purpose)?
- Could the SIMS serve a broader purpose to enable closer connections between farmers and citizens and improve the capacity for mutual understanding and joint-problem solving? If yes it could, what are the alternatives to the SIMS and how do they compare?

The answer to these questions will help determine how the project will evolve during the third loop of the design process:

- Will the SIMS be developed as an application with a narrow commercial application and/or with broader social outcomes in mind?
- What additional stakeholders will have to be included after the second loop is finished (e.g., a commercial partner, if the project goes commercial)?
- To what extent is a TD approach suitable or necessary during the third loop?

The third and final major action will be to more systematically integrate knowledge from stakeholders into the design process by using design tools with a track record of supporting TD. Goudswaard et al. (2020) found that no individual tool enables TD. Rather, it is the appropriate combination of tools, that furthermore need to be linked into a specific 'chain of tools' across the design process, that lead to TD. For example, one such chain consists of the tools:

a product on a page

b Belbin's team roles

c process on a page

d quality function deployment

e failure mode and effect analysis.

Working with the external expert, we will build and adapt on the work of Goudswaard et al. (2020) to select or create a chain that has the best fit with our project.

5.2 Maintaining an open discourse while applying a TD approach

A potential issue in applying a TD approach to this project is the organisational context within which the project team is operating, which increases the risk that the project becomes compromised due to political and economic considerations restraining open discourse required for TD to work.

AgResearch, the organisation under which umbrella this project is taking place, is one of seven CRIs that perform the majority of public good research in New Zealand. It is also a limited liability company, fully owned by the Government.[3] The majority of its funding comes from Government and other Crown funded agencies sources. However, it also relies on commercial revenue derived from contracted service agreements with private commercial entities. This mixed funding model has been a source of debate within the New Zealand science community between those who believe the pursuit of commercial income can distract from the pursuit of research for the public's benefit (e.g., see Science-Media-Centre, 2020). As a result, CRIs align their research aims with Government policy priorities, and therefore may feel unable or disinclined to engage in an open-discourse with key stakeholders, especially when asked to offer opinions that are critical of the Government or the activities of large agribusinesses with whom the CRI may share a commercial relationship (McLeod, 2016). A safe environment where open discourse is stimulated is essential to fostering collaborative learning amongst researchers and stakeholders (Scholz and Steiner, 2015b).

A potential solution to this problem is to involve scientists in the project from more independent research organisations. In the New Zealand context, this means universities who enjoy more unfettered academic freedoms, and are less dependent on Government or commercial priorities, partly because their research is funded by alternate income streams (student fees). Subsequently, the university could play a key role in helping us to identify, clarify and deal with potential biases in the project (see Rosendahl et al. (2015) and Popa et al. (2015) for in-depth discussions involving topics of biases, power structures and reflectivity in transdisciplinary research).

6 Discussion

At the start of a project, researchers or engineers may lack critical information to decide what type of integrated research approach is most suitable, as this paper has illustrated. For example, it may be unclear if and to what degree different disciplines need to be linked or fused (e.g., is a multi-, inter-, or a transdisciplinary approach required; see Lawrence and Després, 2004) or how active stakeholder participation needs to be in order for the project to be successful (e.g., does it suffice to consult stakeholders, or do they need to play a more active, participatory role in the project; see Mobjörk, 2010). This paper has discussed some of the challenges that arise when a suboptimal approach is applied, but also suggests that it is possible to change one's approach over the course of the project. Different cycles of the design process may require different types of disciplinary collaboration and approaches as the focus and scope of the project can evolve over time. It is therefore worth investing time at the outset and end of each cycle to critically evaluate the approach used and whether or not it needs to be adapted or changed for the next cycle.

Further studies could examine the information needs and gaps that researchers have when deciding on what approach and design tools to use for their project, as well as how they go about addressing these gaps (for an overview of design tools, and how they may be used and combined over the life-time of an integrated research project, see Goudswaard et al., 2020). For example, a survey of 'integrated researchers' could identify which information seeking approaches are more successful. For examples of studies into researchers' information seeking behaviours, see Niu et al., 2010; Savolainen, 2017).

Furthermore, it seems worthwhile to study to what extent it is beneficial for teams to change their approach when a project is at a more advanced stage. In our case, we changed our approach after a first design loop, but doing so may be harder and less beneficial after more loops are completed. This could be empirically studied via a cross-case study approach (Yin, 2017). Such a study could, for example, include cases that encountered problems at different stages in the development process. More generally, research in this area stands to benefit from more transparency about the difficulties and mistakes that scientists and other stakeholders make when setting up and undertaking integrated research projects (see also Zscheischler and Rogga, 2015).

For those at the outset of an integrated research project, the case study outlined in this paper indicates that more explicit discussion and consideration of the appropriate research approach would have been useful. An incorrect approach may be avoided or recognised as such at an earlier stage. For those considering changing their approach during a project, we believe the case study will provide a useful example to inform their own response.

7 Conclusion

In this paper we have presented the design of a shared information management system (SIMS) to support smallholders in the agri-food sector to implement hyper-transparency schemes and we have discussed its ongoing development process. We explained how our approach has been evolving over the course of this process from an unstructured, loosely coordinated approach that fell somewhere in between multi- and interdisciplinary research on the integrated research spectrum, towards an approach that is starting to be informed more by transdisciplinary (TD) design principles.

The initial approach, in retrospect, had several short-comings, most important of which was the lack of systematic integration of stakeholder knowledge. This had two main causes. Firstly, stakeholders were consulted on an ad-hoc basis and were not treated as partners to the project. Furthermore, while many stakeholders would probably stand to benefit from the SIMS, each individual actor would also be better off if somebody else would contribute their time to its development. This likely limited the willingness of stakeholders to contribute to the project.

Secondly, while we developed structured and semi-structed techniques for gathering insights from those stakeholders that did participate in the project, we did not employ a structured approach to translating those insights into actionable design tasks and parameters.

We have detailed in this paper how we are planning to address these challenges throughout the remainder of the project. This includes giving individual stakeholders an incentive to participate in the project, as well as developing a 'chain' of design tools that will support the project team in applying TD principles systematically across all stages of a design or development loop (Goudswaard et al., 2020).

This case study has reflected on the shortcomings of an ongoing project and detailed how the team identified these shortcomings and plans to mitigate them. Such a case study is relatively novel in the literature and thus the lessons learned should act as a valuable resource, inparticular as the importance of intergrated research grows.

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Notes

[1]Although some researchers use the term 'cross-disciplinary' instead of 'integrated' research, the former has also been used in the literature to refer to a specific type of 'beyond disciplinary' approach (Goudswaard et al., 2020). Hence, to avoid confusion, we use the latter term.

[2]These are government owned entities that undertake research for the benefit of New Zealand and which are split along sector lines.

[3]Through two Ministries: the Ministry of Business, Innovation and Employment and the Ministry of Finance.