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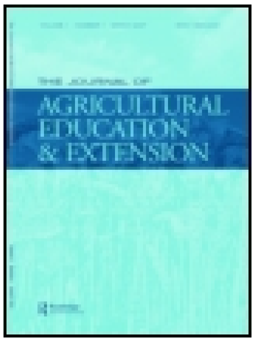

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Managing end-user participation for the adoption of digital livestock technologies: expectations, performance, relationships, and support

J. Schillings[a], R. Bennett[a] and D. C. Rose[b]

[a]School of Agriculture, Policy and Development, University of Reading, Reading, United Kingdom; [b]School of Water, Energy, and the Environment, Cranfield University, Cranfield, United Kingdom

ABSTRACT

Purpose: End-user participation is often encouraged to promote the uptake of Digital Livestock Technologies (DLTs). However, managing participation during DLT development can be challenging. We explore how participation decisions can impact end-users' engagement and attitudes towards the process, before suggesting strategies for improved management of the participation process.

Methodology: We explored the experiences of end-users (e.g. farmers and farm assessors) and other stakeholders (e.g. developers, researchers, industry) involved in the development and testing of DLTs on UK farms, using semi-structured, in-depth interviews ($N = 31$).

Findings: Participation can help develop technologies that better align with users' needs, promote learning, and encourage feelings of ownership. However, participation can be a double-edged sword. Inadequate levels of involvement, management of stakeholder relationships and expectations, and available support can negatively impact end-users' engagement and attitudes.

Practical implications: Our study highlights the importance of understanding how management decisions during the participatory development of DLTs can influence the engagement and attitudes of end-users towards the process.

Theoretical implications: The study contributes to the participation literature in agriculture and demonstrates the importance of using a critical lens to avoid making normative assumptions that participation necessarily promotes uptake in a linear, uncomplicated fashion.

Originality/Value: Participation is seen as key for technology adoption. However, the potential downsides of participation have received less attention in relation to the engagement of end-users in the process.

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CONTACT J. Schillings j.schillings@pgr.reading.ac.uk School of Agriculture, Policy and Development, University of Reading, Reading, RG6 6UR United Kingdom

Introduction

As global population grows, so does global meat and dairy consumption (OECD/FAO 2021). Alongside this challenge is the growing concern over animal welfare, as consumers increasingly care about the ways in which production animals are raised (Alonso, González-Montaña, and Lomillos 2020). However, meeting the needs of increasing numbers of animals is becoming more challenging as the number of farmers declines. The potential of Digital Livestock Technologies (DLTs) is therefore increasingly highlighted, as they are designed to help farmers improve livestock management. DLTs include a wide range of technologies, from smartphone applications through to more sophisticated Precision Livestock Farming (PLF) technologies which allow the continuous, automatic and real-time monitoring of animals (Berckmans 2014). This includes heat or disease detection, monitoring feeding behaviour and animal location using sensors, cameras or even sound-based systems (Schillings, Bennett, and Rose 2021b). Farmers can track changes in conditions or behaviour, allowing them to make timely decisions, thus improving productivity, animal health and welfare, whilst limiting financial losses.

Studies suggest, however, that the adoption of DLTs is currently low in many places (Gargiulo et al. 2018; Silvi et al. 2021). Adoption rates depend on factors such as farm type, herd size, husbandry system or farmers' age, education, and IT skills (Pierpaoli et al. 2013; Gargiulo et al. 2018; Groher, Heitkämper, and Umstätter 2020). Adoption factors include cost, performance, a lack of awareness about existing technologies, or data privacy and interpretation (Borchers and Bewley 2015; Drewry et al. 2019; Silvi et al. 2021). Many DLTs still lack accuracy and validation (Gómez et al. 2021; Larsen, Wang, and Norton 2021; Stygar et al. 2021), which can affect farmers' trust and attitudes towards them (Schillings, Bennett, and Rose 2021a). Although factors influencing adoption have been widely studied in the agricultural sector, less attention has been paid to the ways farmers adapt to, and make use of these technologies (Eastwood, Chapman, and Paine 2012; Rose et al. 2016).

Several models and concepts have been used to explain the process of technology adoption by farmers, each identifying a range of farmer-centric, technology-centric, and wider socio-political environment factors influencing adoption. These include the Technology Acceptance Model (see Pierpaoli et al. 2013), the Triggering Change Model (Kvam, Hårstad, and Stræte 2022), Normalisation Process Theory (Kaler and Ruston 2019), and user readiness (McCampbell 2021). Rose et al. (2016) adapted the Unified Theory of Acceptance and Use of Technology (Venkatesh 2003) to the use of decision support tools in agriculture. They gathered the core factors that influence behavioural intentions such as relevance to users, ease of use, and performance. These are affected by modifying factors (e.g. age or IT skills). Facilitating conditions (e.g. integration into farmers' workflows) and driving factors (e.g. satisfying legislative or market requirements) directly influence uptake and use. These factors highlight the importance of identifying farmers' needs and adaptation challenges, particularly considering the complexity of some technologies.

Many systems are based on what developers consider priorities, focusing on a specific area as a result of a 'technology push', meaning they are not always adapted to farmers' needs (Lindblom et al. 2017). A lack of alignment with their expectations can cause them to ignore the technology, even after it has been installed on-farm (Rotz et al. 2019). To avoid developing inappropriate technologies, adopting a co-design or farmer-centred approach is increasingly encouraged (Kaler and Ruston 2019; Eastwood, Turner, and Romera 2022). We note that there is a vast literature on user participation in technology development across sectors and topic areas; here we build on previous studies that focus on user participation in digital livestock technology design and implementation. From the wider literature, we know that there is a wide spectrum of participation; from extensive involvement of end-users in processes of co-production and co-design, where users can shape projects and contribute knowledge, to much less involvement where users are merely informed about or coerced into actions (see e.g. Arnstein 1969; Reed 2008; Bell and Reed 2021). The same is true in agriculture where farmers or other end-users (e.g. vets, agronomists) can be involved from the early stages of technology development or at a downstream stage in prototyping, on-farm testing, or even at the point of scaling (Kenny and Regan 2021; Eastwood, Turner, and Romera 2022).

Participatory approaches can help better identify farmers' needs, reduce the risks of overlooking the issues that farmers want to address and ensure that their tacit knowledge is incorporated (Eastwood, Chapman, and Paine 2012; Ingram 2014). This can lead to improved technologies, social learning, the development of a sense of shared ownership, positive changes in perceptions towards decision tools, and increased adoption and adaptation (Jakku and Thorburn 2010; Hennessy and Heanue 2012; Valls-Donderis et al. 2014). Cooperation and communication with farmers are crucial for the success of innovation systems, particularly during the testing and validation phases, where farmers act as 'beta testers' (Busse et al. 2015). Thus, participation can make a direct contribution to the key factors influencing technology adoption by farmers (Rose et al. 2016).

More participation does not, however, necessarily mean better outcomes (Hoffmann, Probst, and Christinck 2007; Neef and Neubert 2011). There are several challenges in doing participation, including managing conflicts, identifying appropriate stakeholders, and building trust (see Reed 2008). Strategies for participation include accepting the differences between farmers and developers in terms of epistemologies and ensuring that farmers' experiential knowledge can be combined with the technology (Hoffmann, Probst, and Christinck 2007; Higgins et al. 2017). It also means building trust by ensuring that projects are sufficiently flexible and that developers understand farmers' priorities (Bruges and Smith 2007). In turn, this can help maintain farmers' commitment and enthusiasm for a project.

Other challenges of participatory development exist: they can be costly, time-consuming, and slow down development (Kerselaers et al. 2015). The ability of different stakeholders to adapt to different opinions; aligning diverging interests and considering the degree to which actors are involved, can be particularly difficult in co-producing innovation (Klerkx and Nettle 2013). While restricting stakeholders to discussing technical aspects and logistics may limit success, a balance must also be found in terms of the frequency and nature of interactions between stakeholders to avoid 'participation fatigue' (Neef and Neubert 2011).

Building on previous studies, we use two case studies to explore how participatory processes can influence the engagement and attitudes of end-users towards digital livestock technologies. We critically evaluate how the process of participation can be managed appropriately to overcome potential pitfalls and use a critical lens from the outset to avoid making normative assumptions that participation necessarily improves adoption outcomes in a linear, uncomplicated fashion. Though our case studies focus on DLTs, our recommendations on how to manage end-user participation are likely to be applicable to the development of other technologies across the agricultural sector.

Material and methods

A qualitative approach was used to obtain rich data on end-user experiences within the context of the two case studies. Case studies allow the in-depth exploration of complex phenomena that occur in real-life settings (Crowe et al. 2011). Here, the aim was to understand how end-user participation can affect attitudes and engagement in participatory processes. In our case studies, end-users were farmers (Case Study A) and farm assessors (Case Study B) and we also included perspectives from developers, retailers, and researchers involved in both. Ethical clearance was granted by the University of Reading Research Ethics Committee.

Case study descriptions

Case study A: Cattle mobility and body condition scoring

Body Condition Scoring (BCS) and mobility scoring (MS) are measures that are often included in cattle welfare standards due to their impacts on productivity and animal welfare. These measures are usually taken by humans, introducing possible biases and errors. Automating these measures can help reduce these risks while obtaining a regular feed of information. Thus, a digital, vision-based system to monitor BCS and MS in dairy cattle was developed by a private technology company and tested on 11 farms in the UK. Nine of them volunteered to test the system as part of a quality assurance programme that had an interest to automate this data collection, whilst two others were brought on board by the technology company to test the technology. The system scores the cows each time they pass under the camera, which is placed above a race (usually as they exit the milking parlour). This provides real-time data which can be accessed online by participating farmers. All pilot farms volunteered to have the camera installed and did not have to pay for its installation.

Case study B: Smartphone application

A smartphone application was developed by a UK research institute for the assessment of emotional expressivity and well-being in farmed animals. It was licensed by a UK retailer to assist with further development and testing and enable supply chain staff to assess animals' emotional wellbeing and better manage their quality of life. The application can be applied to different livestock species (including cattle, poultry, pigs, sheep, goats, and salmon), allowing farm assessors from different supply chains to conduct assessments on animals' emotional experiences. Assessments are based on customised descriptive terminologies balanced for positive and negative emotional expressivity that were developed participatively by key stakeholders (including farm assessors, veterinarians, farmers, and others e.g. supply chain directors). These include, for example, terms like 'playful', 'distressed' or 'relaxed'. This was guided by the lead researcher who developed the method on which the application was based. After observing the expressive demeanour of animals during farm visits, farm assessors score each descriptor using sliding scales. The application then integrates these scores through multi-variate statistical analysis. This produces a graph locating visited farms in overall patterns of animal emotional well-being. The graph can be used by assessors to make comparisons between farms and to discuss with individual farmers how the emotional well-being of animals on their farms may be managed or improved.

For convenience, we used the term 'developers' to include technology companies and staff (e.g. technicians) involved in technology design and development. The terms 'stakeholders' and 'participants' are used interchangeably to include all people involved in the case studies, while the term 'users' include those using the technologies (i.e. farmers and farm assessors).

Semi-structured interviews

In-depth, semi-structured interviews were used to obtain detailed accounts of participants' experiences while ensuring that the discussions addressed our research questions. The interviews were conducted by the first author, using topic guides adapted to each stakeholder (Table 1). Two rounds of in-depth interviews were conducted for case study A. The first round involved the initial 11 farmers and was conducted before they were using the technology. The interviews took place between August 2020 and May 2021 and were held for 46 min duration on average, via the phone or using video conference software (e.g. Microsoft Teams) to remain in line with the COVID-19 pandemic restrictions in the UK at the time. Discussions revolved around general attitudes towards DLTs, adoption, and expectations about the trialled technology. Due to compatibility issues, or some farmers having sold their cows during the project, the second round of interviews was conducted with nine of the 11 farmers, in addition to two technology developers and a stakeholder working for a farm assurance scheme organisation involved in the project. To the author's understanding, the technology developers, who were developing the software and hardware, did not have a specific farming background

Table 1. Topic guide used to conduct semi-structured in-depth interviews.

Discussion details	Theme
Introduction to research topic	Introduction Aims of the study Confidentiality reminder
Participants' roles	General information Involvement in the project Aims of the project and technology
Experience with technology	Frequency of use How it works Experience of implementation Data use Attitudes towards the technology
Participation	Experience of being involved Facilitating conditions (communication, feedback, support) Benefits Challenges and impacts Lessons learned
Perspectives and conclusion	Use of DLTs within the wider industry Impacts on stakeholders e.g. farmers, consumers, animal welfare Confidentiality reminder

but were involved in farming-related projects for several years. These were held for 53 min duration on average, using the same platforms, between March 2022 and April 2022. Discussions revolved around experiences implementing the technology, farmer participation in technology development, communication with stakeholders, and attitudes towards the technology.

The same topics were discussed with the stakeholders involved in the testing of the smartphone application during a single round of interviews held in May 2022. The lead researcher provided contact email addresses for 21 stakeholders of the retailer's supply chains who were involved in trialling the application and who were willing to be contacted by the first author. Of these, 16 stakeholders involved in the testing of the application and covering different species (cattle, swine, poultry and fish) including farmers, farm assessors (some of them were also farmers themselves), supply chain directors and others involved in the project (e.g. project manager, coordinators) agreed to be interviewed. Interviews were also conducted with the lead researcher. Interviews (N = 17) were conducted using the same platforms and lasted 50 min on average.

Quotes from case study participants were used to support statements in the results and discussion sections. For case study A, we identified farmers with 'farmer 1' to 'farmer 11', and developers with 'developer 1' and 'developer 2'. Due to the variety of participants in case study B, the different stakeholders were identified with 'participant 1' to 'participant 16' for simplicity.

Qualitative data analysis

The interviews were recorded using a smartphone or software (e.g. Microsoft Teams) recording options. The interviews were transcribed verbatim by the first author, which allowed her to familiarise herself with the data (Braun and Clarke 2006). The data was then analysed thematically. A qualitative data analysis software (NVivo 12) was used for coding, guided by methods from Braun and Clarke (2006) and Ritchie (2014). An initial thematic framework was produced, with themes and sub-themes covering the aims of the study. Data were then coded into these themes, with new themes emerging throughout the process. They were then sorted, and each theme was reviewed, sometimes resulting in the deletion, or merging of themes. Data summaries were then produced for each theme and interview, allowing to draw out key elements and underlying dimensions that guided data interpretation.

Results

Approaches to participation

Our case studies sit in specific places on the spectrum of participation. In both case studies, end-users were involved in the testing of the DLTs, although in case study B, participants were involved at an earlier stage of method development, making use of the fact that the application allows users to insert their own customised descriptive terms. Both used a prototyping participatory approach, which aims '*to observe user interactions, detect potential failures, and refine the design towards an easy and appealing user experience*' (Steinke et al. 2022, 3). Here, both technologies were advanced prototypes, but not finished products. While using an advanced prototype means it is difficult for developers to 'backtrack', it also allows exploration of operational aspects, new functionalities and issues to solve (Cerf et al. 2012).

Case study A

A trial network of farmers was used to test the camera on their farms. Farmers' involvement was an important aspect of technology development according to the quality assurance worker, who said: *[w]e need farmers to be part of innovation projects like we have done; from the start, to help co-develop it*. Technical issues in addition to external challenges such as the COVID-19 pandemic affected developers' ability to visit the farms and delayed the project by several months. Whilst the system was operational for two farmers, others were not able to use the technology. Issues ranged from power and connectivity issues, hardware and software adjustments, compatibility issues and unreliable data; leading technicians to visit the farms on several occasions. During these visits, technicians ensured that farmers' and animals' routines were not interrupted by their presence. This was well received by farmers, who described them as being very professional when out on farms. The need to focus on addressing technical challenges and a lack of resources was seen as a barrier to including farmers in early decisions. As one developer said:

> *It's very little point in having a whole discussion about what farmers want if we are unable to deliver it.* (Developer 1)

They also added being wary about asking for too many opinions, thinking it could have compromised development:

> *You have to be careful; too many cooks spoil the broth. If you have too many people inputting things, you can end up making something that nobody is happy with.* (Developer 1)

Developers were informing farmers and taking feedback individually as they went, such as when out on farms. Farmers mentioned having attended a single meeting since the installation, during which developers gave details about the issues encountered and the steps taken to address them. Farmers were thus not able to share their experiences with others throughout the project.

Initial training opportunities included informal, one-to-one demonstrations of how the data platform worked, although further training was planned once issues were sorted. Some farmers mentioned having experienced poor backup and a lack of communication. One farmer stopped hearing from the company following changes made on the farm. They said:

> *It was taken down and then we said, once we get the new exit race complete, you can come back, and we can fit the cameras. But that never happened.* (Farmer 5)

Another farmer mentioned the short notice developers had given them to organise the stakeholder meeting, during which they had been asked for a testimonial despite not being able to use the system. They said '*[t]hey were seriously running before they can walk*'. (Farmer 6)

Case study B

Participation was also considered a key element by the lead researcher to keep users engaged and to give them a sense of ownership. As the lead researcher said:

It's very important for me that (the method) is developed and trained participatively, you know, that we work together with the farmers and the staff to develop the particular terms.

They organised meetings for each supply chain, including farm assessors, farmers, and other experts such as veterinarians. Participants were shown videos of animals in a variety of environments to generate the descriptive terms they believed best described the animals' emotional expressivity. Following discussions, participants selected and defined lists of approximately 20 descriptive terms per species to be used during the assessments. During these sessions, participants were also invited to provide feedback on the application and make suggestions for improvement. Farm assessors were generally positive about the participation process and were satisfied with the opportunities to provide feedback through regular stakeholder meetings, during which they were also able to keep up to date with developments. They had regular training opportunities, although external barriers such as the COVID-19 pandemic meant that training was undertaken online. Participants were also satisfied with the level of communication with the lead researcher and their ability to guide and support them. However, some mentioned that more direct contact with the application developers to obtain technical support would have been beneficial.

Noting that the level of participation varied between case studies, we discuss the outcomes of participation and how these impacted users' engagement and attitudes towards the participatory processes.

Impacts of participation

In both cases, participation had a positive impact on technology design, as it helped make DLTs better aligned with end-users' needs. There were also positive learning outcomes, although feelings were mixed in case study A. Similarly, participation had varying effects on users' engagement in the process and on the confidence they had in the systems (both positive and negative effects).

Improved alignment with users' needs

The differences in terms of farm location, systems, and designs, allowed developers from case study A to gain a breadth of experience that enabled them to make the technology more reliable and applicable to different systems. As a result of user feedback, developers believed they were able to move forward quickly and to better understand the challenges. One developer from case study A said:

Because everywhere was different, we're coming up with different problems on different farms, which is exactly what you want; you want something that's very varied so that you can address all issues as and when they come. (Developer 2)

Farmers from case study A emphasised the need for the system to be integrated with other farm management software, which developers had started to implement. As they noted:

It's not so much the technology working, it's how it integrates with everything that you are already doing (…) it has to integrate with our working day. (Farmer 4)

Involvement of the different stakeholders in the development of the application (B) helped to ensure that the descriptive terms generated were in line with day-to-day observations on-farm and to develop an application that was practical, easy to use and easily integrated. As an assessor said:

> *Farmers really are experts in their species (…) they're around these animals every single day, (their input) is really valuable to make sure that they we've got terms that work for the species.* (Participant 2)

Stakeholders from case study B also had opportunities to suggest new features to the existing design which were discussed with the lead researcher and incorporated by developers. This included a feature allowing to add more details to the assessments such as weather conditions, time of the day, and other factors that could have an influence on the assessments.

Learning outcomes

Case study B involved training sessions in which stakeholders were informed about the assessment methodology and its technical representation in the mobile application. Following that, they were invited to discuss their understanding of different livestock species' behavioural and emotional expressions, and the potential relevance of the assessment method for managing animal welfare on their farms. They then selected a set of customised descriptive terms they considered suitable for their supply chain and assisted with defining the meaning of each descriptive term. This process generated learning and greater awareness of how and why animals behave in different ways. Working alongside development also helped increase participants' capacity to adapt to the system. One participant said *[W]hen you're part of the concept, then you understand its application, I suppose*. (Participant 9).

In case study A, feelings around training opportunities were mixed, as while some believed the technology was straightforward enough to understand, others felt that training did not allow them to make the most out of it. They said:

> *I mean, it's not complicated to just click and find stuff I suppose, but there might be a whole lot of things you can do on the website that I have no idea.* (Farmer 9)

Another farmer was also critical:

> *It was like a two-minute whistle-stop tour (…) I knew so little about it; I had no inclination to even try and learn.* (Farmer 7)

According to developers, however, the technical issues they had encountered, the global pandemic situation, and farmers' lack of time made it challenging to organise training sessions. Reflecting on this, a developer said:

> *I think there's a bit of that hesitancy on our part; and farmers are always busy, so you just grab 10–15 min with them and then they're off to do whatever they were doing before (…) I think there is a need to get everybody together to sort of go through it.* (Developer 2)

They mentioned that some farmers were experiencing issues with the technology, but due to the distance and travel restrictions caused by the pandemic, it was not always possible to offer support. The same developer said:

I think we could have dealt with that better. (…) Either pop out and deal with it or speak to them over the phone or do it remotely. I guess with the pandemic and everything, that didn't help with travelling.

User engagement

The importance of end-user engagement was emphasised by several interviewees. A farmer from case study A said:

You can have all the knowledge in the world, if you can't engage your audience or your customer (…) it's pointless and hopeless. So that might be something for (companies) to understand: how the farmers will perceive their product and will think about it. (Farmer 4)

The same farmer discussed the stakeholder meeting during which developers gave information about the development process. They said:

I didn't appreciate how much work they have done to drive the product forward (…) having had it explained, I'm now fairly enthusiastic about it. (Farmer 4)

A developer of the camera technology (A) felt that participation had helped to build relations with farmers:

I think it helped build relations because we were there quite often and we were quite slick and we didn't cause them too many problems, I hope. (Developer 2)

However, some farmers mentioned being disappointed by the developers' approach and pointed to a lack of communication and engagement, which impacted some farmers' motivation and interest in the project:

I've no idea who they were. The only contact we've ever had was (the technician) who came and installed the camera and fixed the technical problems, which is a strange way to run a trial, isn't it? (Farmer 2)

Some of them mentioned how they felt a lack of interest from developers in farmers' experiences, which did not encourage them to make use of the technology. As a farmer said, '*[i]t was just like, well, if they're not looking at it, I'm not looking at it*' (Farmer 7).

This lack of communication also affected another farmer's attitudes towards developers. Whilst this farmer had an operational system and was satisfied with the technology, this lack of support resulted in them being more likely to invest in the system if it came from another firm.

Some farmers also mentioned the limited opportunities to discuss with other farmers, which also affected their motivation to use the technology. The importance of feedback from peers has been emphasised by a farmer, as it motivates them to make use of it. They said:

A lot of farmers will take the opinion of other farmers (…) to see how they found it. Often, farmers will have good little hints and tips on how to make the most of it. (…) Then, when it comes on to your farm, you make a big effort to use it (Farmer 9)

Participation in the development of the mobile application (B) clearly helped one participant to feel more closely involved with the project team. They said:

> *When I was invited to this meeting, I actually laughed. But see, when I started to develop the terms along with (the researcher) and the rest of the team, then I started to get better buy-in.* (Participant 14)

The ability to decide on the descriptive terms used in the app's welfare assessments and to provide regular feedback gave participants a sense of ownership and a desire for the technology to be successful. One of them said:

> *You feel (…) a slight sense of pride in actually being involved with it and wanting to kind of get it to fruition.* (Participant 2)

Yet, the fact that application users generally only had contact with the lead researcher led some to feel distanced from technical support.

Confidence and attitudes towards DLTs

Technical performance during the participatory process was a source of positive and negative impacts. A farmer involved in developing the camera was prepared for glitches and set his expectations accordingly. They said:

> *I expected there to be a few problems along the way. I think if (…) it ran for absolutely bang on first time, I would have been very, very surprised (…) So, I think it's all been pretty good.* (Farmer 8)

Confidence in technologies and trust in technology developers were important factors which could be influenced during the process of participation. In case study B, the process helped build trust between users and the lead researcher, and towards the approach. One participant said, '*[t]here was independent, scientific rigour and research behind the process (…) that's really why it appealed*' (Participant 15).

Prototyping is a process designed to identify flaws in a system and resolve them. But there is a risk, which is relatively unacknowledged by the literature, that introducing a flawed technology too early can negatively affect user confidence and attitudes towards the technologies. A lack of accuracy and reliability such as when technologies engender too many false positives can impact users' confidence in a system and hence its use. As one farmer said:

> *If you start crying wolf on a regular basis and it's proven not to be reality, then the confidence just goes (…) Inevitably, human nature means that you stop looking at it and using what it can tell you.* (Farmer 4)

Witnessing the challenges and changes over time also led farmers from case study A to lose confidence in the technology. As one farmer said about body condition scoring:

> *[…] the drops were almost too big to be possible, losing a quarter of a condition score in two days. So, with that you wonder, is the system right?* (Farmer 6)

Another farmer mentioned how this loss of confidence affected uptake:

> *I gotta be honest, the longer it's going on, the less confidence I've got in it, and the less likely I am to probably want to purchase it.* (Farmer 7)

Developers were particularly aware of the difficulties related to farmers not seeing immediate results and mentioned facing a '*big hill to climb*' (Developer 2) to gain their trust back. One of them said:

> *Farmers that have been on this trial will be the most difficult to make happy (…) Those guys saw things not working, things breaking, people up ladders, or incorrect decisions because we didn't know what was right and what was wrong.* (Developer 1)

Despite positive views held about the participation process in case study B, some participants also came across technical challenges, including a lack of phone compatibility or technical glitches (e.g. the application freezing or dropping out during its use). They also expressed concerns about the application being publicised when technical issues still needed to be resolved, and about the uncertainty around the outcomes of the project, such as how the data would be used. As a participant mentioned:

> *I think it came out too quickly on (the media) (…) we hadn't actually collected much data by that point, and it was marketed, and we were like, right, we still don't have a platform for everything to go on (…)* (Participant 10)

Another said: *I think everyone's frustrated that there's a big push on that and it doesn't properly work.* (Participant 4)

Discussion

End-user participation is widely promoted to increase the adoption of innovation (Reed 2008; Jakku and Thorburn 2010; Eastwood, Turner, and Romera 2022). Lessons from the case studies highlight how participation can improve trust, technology design, motivation, and foster learning. Similar observations have been made in previous literature. Involvement was shown to promote enthusiasm in a system, as well as trust and a better understanding of its purpose (Oliver et al. 2017). In a study by Jakku and Thorburn (2010), a participatory approach allowed farmers to gain trust and confidence in the scientists involved in the project, even though they had initial reservations. Similarly, Oliver et al. (2012) suggest that a benefit of co-constructing decision support tools is the ability to establish trusting relationships with the farming community and improved technology performance.

Aligning with users' needs and expectations is another recognised benefit of participation (Carberry et al. 2002), and considering users' expertise (e.g. integrating local and tacit knowledge) is crucial for the development of agricultural innovations. By involving users with different perspectives and skills, participation can lead to more socially robust end results and improved technologies (Jakku and Thorburn 2010; Lindblom et al. 2017). Srinivasan et al. (2022) reported that including different user perspectives allowed the enhancement of the relevance and legitimacy of an irrigation scheduling tool for New Zealand pastoral farms. Similarly, co-designing a smartphone application allowed the identification of users' needs and technical solutions that helped develop desirable features and functionalities (Kenny et al. 2021).

Enhanced learning outcomes are also a commonly mentioned benefit of participation processes. Jakku and Thorburn (2010) developed a framework which highlights the potential for decision support tools to act as boundary objects by facilitating communication and fostering co-learning among stakeholders involved in their development. Learning is an integral part of the participatory processes both for researchers and end-users, as they can share their thoughts and get a better insight into the decision problem being discussed (Kerselaers et al. 2015; Bruges and Smith 2007; Rossi et al. 2014).

Our study illustrates, however, that participation between developers and users can be a double-edged sword. This is sometimes acknowledged in existing literature, although often relegated in favour of an emphasis on constructing participatory frameworks. In the following sub-sections, we explore these pitfalls further and discuss how participation in technology development can be managed to overcome them. We acknowledge that participation can play a key role in adoption, but four areas of consideration are required in planning approaches (see Figure 1): (1) Level of stakeholder involvement, (2) Managing expectations, (3) Managing relationships, and (4) Support for learning.

Level of involvement

The extent to which end-users are involved in participation is an important factor to consider. In case study A, the extent to which participants were involved was limited and progress was not necessarily shared with farmers, who mostly interacted with technicians. Being mostly exposed to the issues and not being able to witness progress could explain a loss of engagement. In case study B, there was a separation between the application developers and users. Reflecting on the literature, higher involvement is generally associated with better outcomes (Valls-Donderis et al. 2014); therefore, developers should be mindful of this when planning participation. However, a balance must be found in terms of when and how to involve the right stakeholders (end-users plus e.g. developers, retailers etc.), as well as how much information is shared with them. ‘More participation’, such as allowing users to be in direct contact with technology developers or involving farmers in discussions about their needs when developers are unsure about being able to respond to their expectations, would likely be counter-productive. To maintain enthusiastic participation, it has been suggested to ensure that end-users can

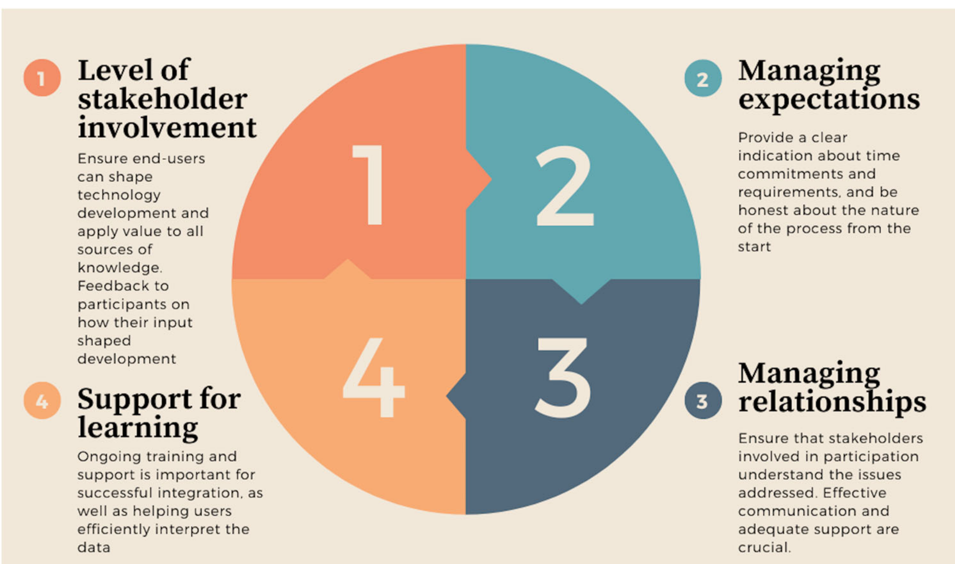

Figure 1. The identified key considerations for participation in technology development.

control or shape the research agenda, which would give them confidence that the project is aiming at reaching their goals (Bruges and Smith 2007). Fostering a good level of participation also requires applying equal value to all sources of knowledge, taking the time to understand user perspectives (Srinivasan et al. 2022), and feeding back to participants how their input has shaped technology development.

Managing expectations

Though it is often assumed that early involvement of users is best, releasing a flawed technology into a use environment brought problems. In this study, technology failures had a negative impact on users' motivation to use technologies and on the confidence they had in them. In case study A, failures and the time taken to sort them resulted in some farmers not trusting the data, and hence not making use of it. Similarly, technical issues affected some of case study B participants' willingness to use the technology, despite a positive perception of the participation process and trust in its scientific credibility. Whilst some participants were expecting issues to occur, technology performance had a significant impact on their intention to use the technologies. This has been found elsewhere, albeit at a slightly later stage in which farmers have already paid. Immature technologies being sold to farmers impacted their confidence in Automatic Milking Systems (AMS) and led to them decommissioning or reverting to conventional milking (Eastwood and Renwick 2020).

Reflecting on their experiences, technology developers from case study A emphasised the importance of managing users' expectations and relationships. They suggested that the optimism shown at the start of the project should be balanced to avoid users feeling disenfranchised and becoming untrusting of the data if such excitement does not transpire. Managing end-user expectations is indeed an important factor to avoid frustration, which can be particularly challenging as these vary among stakeholders (Oliver et al. 2017; Steinke et al. 2022). Steinke et al. (2022) note that the degree of commitment, perceptions of the prototype and the time taken to see results are all aspects that can lead to such frustration. To overcome this issue, they suggest that developers must be honest about the nature of the process from the beginning and provide regular updates about development. Clarity of expectations is also important, with a clear indication for participants about time commitments (Oliver et al. 2017).

Managing relationships

Building trust, honesty, and managing relationships is important when using a participatory approach (Bruges and Smith 2007), as is managing potential conflicts and flashpoints (Reed 2008). In case study A, while developers respected farmers' workflows, they also believed the tool was further down the line than it was. In addition to the lack of stakeholder meetings, this created frustration. Some farmers also noted a lack of communication, and the decisions taken by developers affected farmers' perception of developers' understanding of farming (e.g. by giving them short notice to organise meetings). Similarly, decisions to publicly promote the application in case study B led to frustration in some users, since they were still encountering technical issues and had doubts regarding the outcomes of the project. Ensuring that the stakeholders involved in participation processes understand farming and the issues that farmers need to address is therefore key to building relationships, and so is the availability of developers in terms of providing support and effective communication.

Support for learning

A lack of confidence in the data can impact the use of technology. In a study by Cerf et al. (2012), farmers lacked confidence in the results of a decision support tool for crop disease control, which resulted in them not being willing to change their farming practices. While in case study A, developers appeared to have benefited more than participants in terms of learning outcomes, most stakeholders from case study B mentioned having learnt from the process. This was likely linked to the extent to which participants were involved, with case study B participants having more occasions to share their thoughts with others, in contrast with case study A where opportunities for co-learning were limited.

Findings indicate the importance of having adequate support and training during prototype testing of technologies. Case study B participants were generally satisfied with the training and support provided, which helped them get a better understanding of the application. However, some also reported frustration as communication with application developers other than the lead researcher was limited. Training opportunities were less well received by some farmers in case study A. This had an impact on their perception of the participation process and the developers, particularly those with limited IT skills.

Ongoing training and support during on-farm testing is thus particularly important for successful integration into daily routines, helping users efficiently interpret the data (Busse et al. 2015). This was emphasised by Kenny and Regan (2021), who highlighted farmers' support on using the technology as important to not frustrate participants, especially those with poorer IT skills.

Limitations

Whilst both case studies gave interesting insights into the experiences of stakeholders involved in the testing of prototypes, participants' input in the overall design of the methods and technologies remained limited. In addition, the interviews were conducted at early stages of technology use, and the qualitative nature of the study means that the sample used does not allow to make generalisations. Thus, it would be interesting to study these impacts in case studies that have used other approaches to participation (e.g. user-centred design), conduct interviews at later stages to get a better insight into users' experiences, and with larger samples (and/or make use of quantitative research methods). Finally, contact details for potential participants for case study B were provided by the lead researcher, introducing a possible bias regarding the attitudes of participants towards the technology. However, those participants also reported issues with and concerns about the development process, suggesting that this bias was minimal.

Conclusion

A variety of factors influence the adoption of DLTs. However, implementing technologies does not necessarily lead to long-term use. Often, adaptation to technologies and suiting users' needs and workflows is a challenge. To address this issue, participation in technology development is often promoted. However, the level of end-user involvement, how relationships and expectations are managed, the performance of technologies and the quality of the support and training provided can have an influence on users' attitudes and engagement in participatory processes. When these aspects fail, this can impact participants' engagement, create frustration, and impact confidence and motivation to use technology, as well as trust in technology developers. In contrast, well-managed participation processes have many benefits, as they allow tools to be better aligned with users, promote learning, and facilitate adaptation. Finding the right strategies is therefore important to promote technology acceptance and uptake. Future studies could make use of larger samples or mixed methods approaches to better understand the pitfalls of participation and refine those strategies further, including in the wider digital agricultural technologies sector.

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Notes on contributors

Juliette Schillings is a PhD student at the University of Reading. She holds a BSc in Biomedical Sciences from the University of Paris Descartes and an MSc in Process and Engineering in Food and Environmental Sciences. She also studied an MSc in Applied Animal Behaviour and Animal Welfare at the University of Edinburgh. Her research interests include animal welfare, animal behaviour and digital agriculture.

Prof. Richard Bennett is Professor of Agricultural Economics at the University of Reading. He has broad research experience across agriculture and food but with a particular research interest in the economic, social science and policy aspects of animal health and welfare.

Prof. David C. Rose is Professor of Sustainable Agricultural Systems at Cranfield University. He runs the Change in Agriculture research group, which explores how changes in innovation, technology, and policy affects people, production, and the planet. He is a Geographer by training with previous positions at the University of Reading, University of East Anglia, UCL, and the University of Cambridge.

Data availability statement

Not available due to industry confidentiality.

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