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Insights and Learnings from the Use of Design Thinking for Digital Agricultural Innovation Design

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Abstract

This research contributes to the growing discourse on participatory approaches for digital agricultural innovation design. Specifically, it details practical insights and learnings from applying the first three phases of a design thinking approach to the design of a digital animal health innovation. Design thinking proved effective as it facilitated direct engagement with end users (through focus groups and a co-design workshop) and leveraged specific design thinking techniques (user personas and 'How might we…?' questions). This facilitated the identification of key end-user needs and the co-creation of tailored solutions, successfully informing the tools design. Several context specific insights and learnings are garnered from this study for future researchers aiming to replicate these approaches in an agricultural context. These include due consideration for the busy farming calendar to ensure effective stakeholder participation and engagement with the process; attention to environmental factors when engaging stakeholders on farm; and the recommended use of boundary objects in participatory research to facilitate mutual understanding and rich discussion. This research suggests that considering these factors is imperative for successful participatory design research in agricultural contexts.

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Introduction and Problem Statement

The uptake of digital technologies is extensively promoted in the agricultural sector with digital agri-tech being primed as a 'silver bullet' solution to many of the sectors' challenges (Barrett & Rose, 2020). Digital tools stand to benefit both farmers and the wider farming system directly, promising to improve on-farm profitability (Carolan, 2020), address labour gaps (Ryan, 2023), and make farming systems more efficient, productive, and environmentally friendly (Birner et al., 2021; Regan, 2019). However, despite the overwhelmingly positive narrative surrounding digital technology, surveying data shows patterns of low and slow adoption by farmers (Lowenberg-DeBoer, 2022), denoting agriculture as one of the least digitalised industries.

The social science literature has made significant progress in exploring the reasons behind this tentative adoption. Early research in this area has largely focused on human-centred factors (such as farmer demographics, individual characteristics, psychological factors, and skillset) as key determinants of technology uptake in agriculture (McGrath et al., 2023). However, this focus has arguably been overemphasised, placing disproportionate attention on the farmer as the subject of technology adoption issues (de Oca Munguia & Llewellyn, 2020; McGrath et al., 2023). While understanding human factors remains important for addressing adoption issues, more recent social science research (Prost, 2021; Rose et al., 2018) highlights the need to focus on additional dimensions of technology adoption. In particular, it calls for a shift in our attention upstream to critically examine how and why digital technologies are being designed and developed for farmers; whether these design choices influence adoption, and if alternative development approaches are needed to promote uptake (McGrath et al., 2023).

Theoretical and Conceptual Framework

Shortcomings in Current Methods of Technology Design

Until recently, technology design and deployment have largely been driven by productivist values and supplier companies (Birner et al., 2021), often following a linear development model. In this model, research organisations produce the necessary scientific and technical knowledge needed, with little to no input from innovation end users such as farmers or other agricultural stakeholders (Berthet et al., 2018). As a result, digital technologies are frequently developed in a silo with little opportunity for farmers to say what they need or want from an innovation. Additionally, many technology providers come from industries outside of agriculture, with research and development for agricultural technology often conducted away from the farm (Wiseman et al., 2019). This disconnect means that researchers and technology developers are often too far removed to understand what is going on at farm level, resulting in technologies that are not context specific, do not match the 'on-the-ground' reality of farming, and are not developed to address farmers' needs (Lioutas & Charatsari, 2020; Long et al., 2016). These 'top-down' non-collaborative approaches to innovation development have proved ineffective in delivering technologies to farmers (Seminar & Sarwoprasodjo, 2019), resulting in weak adoption or eventual discontinuation (Steinke et al., 2022).

A New Era of User Centred Digital Technology Design in Agriculture

The Human Computer Interaction (HCI) literature has indicated that these linear methods of technology design are no longer sufficient, owing to changes in how people now use and interact with digital technologies. This body of literature indicates that we need to move into a new paradigm of technology design, where user needs, values, and broader social considerations become the drivers of research, design, and development processes as opposed to being guided by the priorities of technology suppliers and commercial interests (van den Hoven, 2007). This has prompted a shift toward a new era of digital technology design in agriculture, one that is increasingly user centred.

This new paradigm would see that prior to innovation development, technology designers would first get a comprehensive understanding of farmers' needs, feelings, and preferences, and then look to build technologies to address those attributes (Gichamba et al., 2015; Steinke et al., 2022). Using this information to guide technology design ensures technologies are developed to meet farm-level needs and allows technology developers and design teams to focus on problems rather than on design development goals (Hearne et al., 2023). This can lead to better adoption rates due to the relative advantage of the new technologies (Rogers, 2003).

A technology's success can therefore depend on how it is designed and developed, and technology developers, among other actors, can have an important role in reducing innovation uncertainty and in overcoming barriers to adoption (Eastwood et al., 2016). Therefore, the decisions technology designers make, and the methods of technology design they use (Prost, 2021), will be important contributing factors to the success of agricultural digitalisation. Such considerations underscore the call for researchers to move away from 'top-down' to more inclusive, 'upstream' and 'bottom-up' approaches to technology design. It has also been recommended that technology design aligns with the principles of Responsible Research and Innovation (RRI), which includes (a) inclusivity, (b) anticipation, (c) responsiveness, and (d) reflexivity.

Inclusive Approaches to Innovation Design

Responsible Research and Innovation (RRI) has been promoted as a useful paradigm for governing science and innovation; its dimensions encourage active consideration of the end user and important social and ethical factors (Eastwood et al., 2021; Klerkx & Rose, 2020). Inclusion, a key pillar underpinning the RRI framework, is therefore promoted as crucial for future innovation design processes (Rose & Chilvers, 2018). To achieve more inclusive innovation, various methods like participatory design, co-design, and design thinking are increasingly being utilised in the digital agriculture literature (Prost, 2021; Steinke et al., 2022). These approaches facilitate engagement with farmers to build understanding and identify their needs and preferences, as well as including prototyping and testing stages to ensure inclusive design (Prost, 2021). These approaches foster co-creation and co-innovation, leading to more effective and efficient technology development, ultimately promoting adoption.

Purpose

Despite their value, implementing inclusive design principles in innovation development in practice can be a challenge, and little has been documented about experiences of these principles in an agricultural context to date (Eastwood et al., 2022; Steinke et al., 2022). To address this gap, this research contributes to this emerging body of literature by detailing how a design thinking approach was utilised to inform the design of an agricultural innovation. Building on initial experiential learnings (Eastwood et al., 2022; Kenny et al., 2021; Schillings et al., 2023; Steinke et al., 2022), this paper provides context-specific and practical insights gained from applying participatory research to innovation design within an agricultural context. These findings could prove valuable for researchers considering similar approaches in future agricultural practices.

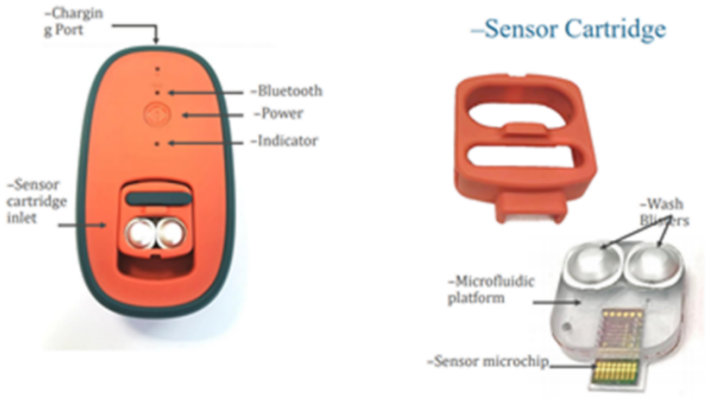
Methods

Design thinking is a five-stage iterative framework that places the user at the centre of the design and development process, ensuring innovations are built around their needs. Its key phases are empathise, define, ideate, prototype, and test. The empathise phase focuses on understanding users' needs and challenges through end-user engagement. The 'define' stage uses findings from stage one to define user problems. 'Ideate' focuses on creating innovative solutions to identified problems, which informs prototype design and development (Prototype). Prototypes are tested in a real-life context (Test) and user feedback drives iterative re-testing until end-user needs are addressed (Hasso Plattner Institute of Design at Stanford, 2010).

This study details the application of the first three phases of this framework – empathise, define, and ideate – to inform the design of a novel animal health digital innovation currently in its very early design stage in Ireland. The proposed tool is a handheld device (see Figure 1) that aims to enable rapid on-farm sample testing, a process traditionally confined to Regional Veterinary Laboratories. The diagnostic device works in conjunction with a smartphone application and biological sensors which can determine whether a sample (e.g., blood, milk, mucus) is positive or negative for an animal illness by identifying and detecting antibodies in that sample. The development of this tool and capability for rapid on-farm testing would allow farmers and veterinarians to identify animal illnesses early and determine appropriate treatment plans.

Figure 1

An Early Conceptual Prototype of the Digital Diagnostic Device



Empathise

The empathise stage aimed to understand the key needs of farmers and veterinarians regarding animal disease detection on dairy farms. It then explored their perceptions of using digital tools to address these needs, focusing on the development of a digital diagnostic tool. Thirty-three participants (23 dairy farmers, 2 agricultural advisors, and 8 farm animal veterinarians) participated in four focus groups in the South and Southeast of Ireland between January and April 2023. Purposive and convenience sampling techniques were used to recruit participants. Focus group discussions were facilitated by the researcher and were recorded, transcribed, anonymised, and thematically analysed using an inductive thematic approach (Braun & Clarke, 2006).

Define

The define stage (April - May 2023) synthesised the empathise stage data to understand key end users and define their problems and needs. This involved developing 'How might we…?' questions and user personas – key design thinking techniques. Themes from the focus group data were reviewed and insight/problem statements were developed for each. These statements were then reframed into solution oriented 'How might we…?' questions. User personas reflect hypothetical archetypes of real people, and usually describe user goals, challenges, and needs. To develop the user personas, transcripts from the empathise stage were re-read, and key user attributes were noted. These were synthesised to create four personas (two farmers and two veterinarians) which represent and help us to understand the 'typical users' of a digital diagnostic tool.

Ideate

This phase utilised the user personas and 'How might we…?' questions to brainstorm innovative solutions to design problems highlighted by end users. For this, a multi-stakeholder workshop was held in the South of Ireland in July 2023. Thirteen participants (6 dairy farmers, 2 farm

veterinarians, 2 technology developers, 2 agricultural advisors, and 1 animal health expert) were purposively recruited to attend. In the workshop, participants collaborated to generate solutions to identified design issues, considering typical user characteristics.

Limitations

Owing to research delays caused by COVID-19 lockdowns, this paper details the application of only the first three phases of the design thinking framework to inform the design of this digital innovation. As a result, it is important to acknowledge that this study does not assess the utility of the entire design thinking framework for innovation design. Therefore, when discussing the value of design thinking within this research, it specifically refers to its value in informing the design of innovations in an agricultural context.

Findings

This section details key insights and learnings from applying a design thinking approach to agricultural innovation. It first outlines how design thinking was useful to inform the design of an innovation that aligned with user needs and facilitated the integration of RRI principles into innovation design. Additionally, it details key contextual findings for enacting participatory design for agricultural innovation, including participant recruitment, environmental factors, and the value of boundary objects.

Alignment of User Needs

One of the key findings from this research is that design thinking proved a useful methodology to ensure that the user was central to the design process in developing a digital technology for use in agriculture. This provided valuable insights that were useful in shaping the design of the innovation to better align with user needs.

Identification of User Needs

The empathise stage was useful in allowing the researcher to gain a deep understanding of the user. The focus groups gave a unique space to farmers and veterinarians to discuss and highlight the real-world challenges they encountered when it came to detecting and diagnosing animal illnesses on farm. These challenges include timing and testing (inadequate testing and testing delays); knowledge and experience of a particular illness (hampering their ability to identify its symptoms); and low veterinarian availability. Through the focus group discussions participants described the negative impacts these issues have including frustration, treatment delays, and increased use or misuse of antibiotics. Following these discussions, participants expressed that their key need regarding animal health on farms is the rapid identification of illness causes and their swift treatment.

In the same focus groups, the concept of a digital diagnostic tool was introduced as a potential solution to this need. Participants discussed the potential viability and value of such a device, as

well as highlighting some concerns such as potential misuse or inaccuracy, which could lead to misdiagnosis or an overprescription of antibiotics. Considering the future potential development of a digital diagnostic tool, participants identified several key user requirements and key design features. The main requirement for the successful development of this tool was that the testing needs to be reliable and trustworthy. Participants also identified that they would need support and education for its use, and that the tool should be easy to use and context specific (i.e., specifically developed to be used on farm).

Addressing These Needs

These identified needs, concerns, and requirements were reframed into 'How might we…?' questions which were then addressed in brainstorming sessions in the co-design workshop. Table 1 illustrates a sample of some of the key co-designed solutions addressing these user needs.

Table 1

Co-designed Solutions Tailored to Align with User Needs

Identified Need (Insight statement)	**How might we…? (Define stage)**	**Co-designed Solutions (Outcomes)**
Users want support and education to operate the device correctly	How might we provide education, support and back- up to users to use this device?	Generative AI support feature Customer Care FAQ / SOP document Graphical instructions Step by step training video
The tool needs to be reliable, and the results trusted	How might we ensure users have trust in the results of this device?	Training Calibration QC analysis Independent Trials
	How might we ensure that results are clear and easy for users to understand?	Traffic light system Reference sheet to compare results
The device needs to be simply designed and easy to use	How might we successfully design this tool for on-farm use?	Bright colour Work offline Durable, waterproof Cover over charging port Large display and font
The tool needs to be context and user specific	How might design features change if it was to be used by farmers or by vets?	More info for vets Easy to share results Vets can test for more

This overall approach was useful in enabling future end users of a digital agricultural technology to share their key values and needs for a diagnostic tool, and subsequently to co-create solutions to address these needs. As a result, the tool's design is user-focused and needs-driven.

Design Thinking as a Vehicle to Implement RRI into Innovation Design

As previously discussed, a significant challenge of RRI is in its practical application, especially in a commercial domain (Pavie & Carthy, 2014). This research supports claims by Kenny et al. (2021) that design thinking can be a useful methodological framework to practically implement some of the principles of RRI to digital agricultural innovation design even within a commercial domain.

Design thinking emphasises empathy and the understanding of human needs. By actively seeking out and engaging a wide range of stakeholders, the design thinking process ensures a broad spectrum of perspectives and needs are considered. This emphasis on the user addresses the pillar of inclusivity in the RRI framework. Design thinking achieves inclusion by identifying and including future end users and key stakeholders in the innovation design process. The methods used in this study (focus groups and a co-design workshop) have been effective in bringing together a variety of voices, including those from the farming community, the agricultural industry, and academia.

Anticipation, another key pillar of RRI, involves forecasting potential negative consequences and risks of an innovation (Stilgoe et al., 2013). For agricultural digitalisation, there have been calls to anticipate the future impacts of technology adoption (Barrett & Rose, 2020). In this study, design thinking principles helped researchers and technology developers to anticipate both user needs and the potential negative impacts and concerns associated with the diagnostic tool before development. This information enables researchers and technology designers to be responsive to stakeholder feedback and emerging societal needs (responsiveness pillar). The user-centric focus also supports reflexivity as researchers are required to consciously set aside their own biases and assumptions about the tool's design in favour of responding to stakeholder values. Therefore, this research suggests that future researchers aiming to implement the principles of RRI into innovation design, can utilise the design thinking framework to effectively achieve this goal.

Important Contextual Findings

This section outlines some important contextual insights and learnings derived from applying participatory design approaches to agricultural innovation. These include participant recruitment and environmental considerations, as well as the value of boundary objects to facilitate understanding and discussions.

Participant Recruitment

Inclusion and engagement with end users are key principles of participatory design research (Interactive Design Foundation, 2023). When employing these approaches to innovation in an agricultural context, farmers are often the key stakeholders for recruitment. Therefore, researchers applying these approaches in agriculture should be cognisant of the farming calendar and associated busy seasons, as this may make it difficult for farmers to engage in the research study. In this study, the projected timeline to complete empirical research in the empathise stage coincided with the busy Irish spring calving season which lasts from January to April. This season is far busier and demands heightened attention and labour on dairy farms (Deming et al., 2019). Consequently, scheduling accommodations had to be made in this study when considering dates to conduct the focus groups, i.e., the first focus group was scheduled in early January (prior to the start of calving season), and the next groups were scheduled for the beginning and end of April (which was at the end of the calving season). This emphasises that when planning participatory research with farmers, recognising the demands of the farming seasons and specific agricultural practices is essential for their engagement with the process.

Environmental Considerations

Considering and assessing the environment within which participant engagement can take place is important, and it is suggested to conduct engagement in environments that are familiar to participants. In Ireland, farmer discussion groups are a common method of stakeholder engagement used by agricultural advisory services. These discussion groups facilitate peer-to-peer knowledge exchange between groups of local farmers, with regular meetings taking place on group members' farms (Hennessy & Heanue, 2012). Mirroring this practice, two of the three farmer focus groups were conducted on participants' farms: one in a farm shed, and the other in a semi-covered collection yard of the milking parlour.

For the latter location, the farmers' farmyard was situated in an unsheltered area on top of a hill, resulting in significant windfall throughout the parlour. This windfall affected the quality of the focus group recording, potentially resulting in a loss of valuable insights during transcription. In this study, this risk was mitigated as data was collected in a variety of formats including written material (flipchart sheets and sticky notes were used during the focus groups to capture participant responses and stimulate discussion). This research found that when conducting participatory and interactive engagement with farmers in farm locations, due consideration should be given to environmental factors which may affect data collection and ultimately the value of the research undertaken. Consideration should be given to factors such as noise, weather conditions, or other external disturbances. Such considerations are important for ensuring the comprehensiveness of data collected in participatory design research within agricultural settings.

Value of Using Materials and Boundary Objects

Design thinking has been a useful method in this study for convening a diverse range of stakeholders. For example, the co-design workshop (ideate phase) included dairy farmers, farm veterinarians, agricultural advisors, an animal health expert, and technology developers. While recognising the wealth of knowledge and experience that such a diverse group brings to

discussions, fostering effective collaboration and communication among such a varied group can present a significant challenge. Successful innovation requires integrating participants' diverse knowledge while overcoming boundaries caused by disciplinary specialisation and varying experience, needs, perspectives, biases, and assumptions. This also necessitates facilitating discussions that are understandable to experts in various fields such as academics, technology developers, engineers, and end users (Caccamo et al., 2023). A key method in overcoming these challenges in this study involved the use of materials as boundary objects.

Boundary objects serve as focal points to facilitate communication and understanding among different stakeholders (Klerkx et al., 2012). They provide a common reference that different stakeholders can use to communicate their own perspectives, as well as understand the perspectives of others, helping to bridge the gap between diverse viewpoints (Caccamo et al., 2023). Boundary objects can therefore help individuals to get a better understanding of what the design is about and how it can affect individuals' normal practices (Klerkx et al., 2012).

In the empathise stage, an image of an early prototype of the digital tool (see Figure 1) was used to make the device concept more tangible. This allowed participants to gain a shared understanding of how the device might practically work and to discuss design features, using the image as a collaborative blueprint. In the co-design workshop, the user personas and 'How might we…?' questions proved useful for participants to form a universal understanding of design issues and end-users' needs in designing a digital animal health diagnostic tool. These played a crucial role in generating solutions to identified design problems by bridging the gap between participants. Rather than considering their own design biases when considering how the innovation should be designed, participants were able to use the personas as a common reference. On many occasions, workshop participants referred to the personas when discussing the key design features of the innovation, for example (extract from the co-design workshop):

> Veterinarian: let's say our lad [in reference to a veterinarian persona] he's busy, not used to tech, definitely the telephone support line would be a good one. I think he's 43, he's of an age where he didn't… like he probably had a PC when he was maybe in his teens. So, he'd much rather pick up the phone and talk to a fella.

Without the use of these materials, the discussions within the design thinking process in this study could have become disorganised and unfocused. The materials used in this study were useful in facilitating collective understanding, in providing direction and focus to the discussions, and ensured that the outcome of the co-design workshop was targeted and specific.

Conclusions, Discussion, and Recommendations

Design thinking approaches can be useful in embedding RRI principles for successful innovation design in agriculture. In this study, design thinking facilitated inclusive engagement and collaboration with key stakeholders to identify user needs, and subsequently co-design solutions to these needs. This iterative process highlighted user needs and concerns related to

an animal health diagnostic tool, which were collaboratively addressed to influence the tools' design. Ultimately, this approach ensures that the tools' design aligns with user needs and is context specific, thereby adhering to the new era of innovation design where the user is central and innovations are needs-driven.

Several recommendations arise from the insights and learnings garnered through this approach which may be applicable for future researchers aiming to implement similar methodologies. When applying these types of inclusive approaches to innovation, several considerations are important for successfully engaging key stakeholders with the process. Understanding the busy farming calendar is imperative for effective participant recruitment and participation. Environmental factors must also be carefully considered to ensure successful and accurate data collection. Furthermore, this research highlights the value of boundary objects in participatory research to foster collective engagement and to ensure discussions are kept on track and are goal orientated. Their inclusion is therefore recommended in such approaches.

Inclusive approaches to digital innovation design are increasingly promoted to improve adoption of digital innovations by ensuring they are tailored to align with farmers' needs and on-farm contexts. This research underscores the value of prioritising inclusion and engagement for digital technology design, demonstrating how these approaches can foster more user-centred innovations.

Future research would benefit from similar studies that provide insights into the process of applying these approaches to innovation design. Given their relative novelty, continued reports and learnings from other applications are crucial to ensure these methodologies are improved and robust, especially when being applied in an agricultural context. Such discourse will aid other researchers and technology developers in effectively replicating these inclusive approaches, ensuring future innovations are both user-centred and responsible.

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supervision, funding acquisition. **T Russell –** Conceptualisation, methodology, writing – reviewing & editing, supervision, funding acquisition.

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