Agricultural Systems 194 (2021) 103248

Contents lists available at ScienceDirect

Agricultural Systems

journal homepage: www.elsevier.com/locate/agsy

Empathising, defining and ideating with the farming community to develop a geotagged photo app for smart devices: A design thinking approach

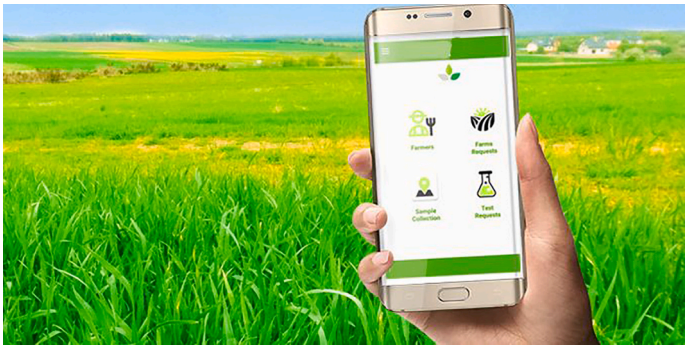
Ursula Kenny [a,*], Áine Regan [a], Dave Hearne [b], Christine O'Meara [b]

[a] Agrifood Business and Spatial Analysis, Rural Economy Development Programme, Teagasc Mellows Campus, Athenry, Co. Galway, Ireland
[b] Telecommunications Software & Systems Group (TSSG), ArcLabs Research and Innovation Building, Waterford Institute of Technology, Co. Waterford, Ireland

HIGHLIGHTS

- Design Thinking was used to develop an app
- Methodological development of the app is presented
- Design thinking highlighted disparate needs, motivations, and intentions for the app

GRAPHICAL ABSTRACT



ARTICLE INFO

Editor: Laurens Klerkx.

Keywords:
Design thinking
Interdisciplinarity
User participation
Innovation
Digital communication

ABSTRACT

Context: There is growing interest and importance for responsible research and innovation (RRI) among academic scholars and policy makers, especially, in relation to emerging technologies in the agricultural context. While the evolution of smart technologies in agriculture has led to an increase of available solutions that can be used by farmers, the RRI process of new farming technology has been minimally detailed in research contributions to date.

Objective: This paper thus aims to describe the first 3 phases of a design thinking process to aid with the development of an agricultural innovation, namely, a geotag photo application for use on smart devices.

Methods: The design thinking approach involved engaging with target users, such as farmers, farm advisors and inspectors, alongside research scientists, app developers and the national agricultural governing body in Ireland to commence the app development process. This paper describes methodology used to elicit the first three major phases of the design thinking approach: empathise, define and ideation. In the first phase a stakeholder mapping activity was conducted, as well as 7 focus groups and 10 interviews with users and other key actors regarding the challenges and needs related to using the app. The define phase included a reflection of results from the first phase and subsequent development of user-personas and problem statements to inform the third phase. The third phase, ideation, consisted of four interactive user-centred workshops, focusing on app needs, in which ideas and solutions were developed and prioritised.

* Corresponding author.
E-mail addresses: Ursula.kenny@teagasc.ie (U. Kenny), Aine.regan@teagasc.ie (Á. Regan), Dave.Hearne@WaltonInstitute.ie (D. Hearne), Christine.OMEARA@WaltonInstitute.ie (C. O'Meara).

https://doi.org/10.1016/j.agsy.2021.103248
Received 24 February 2021; Received in revised form 13 August 2021; Accepted 14 August 2021
Available online 7 September 2021

Results and conclusions: The design thinking approach supported multiple stakeholders to express and evaluate the benefits and challenges they associated with the initial development phases involved in designing a new geotag photo app. It also revealed that, by including farmers and additional actors in developing new farming technology enables technology developers to harness the full value of multiples types of knowledge and expertise. In conclusion, future research on innovation development should consider that by enabling engagement among a wide variety of actors, such as that offered by the initial stages of design thinking, and attending to a greater diversity of values is essential to the development of a responsible, and responsive, digital tool.
Significance: This study is the first to methodically document the early stages of developing a geotag smartphone app using a design thinking approach. This paper will therefore benefit other scholars aiming to include farmers, and other agricultural stakeholders to have an input on the agri-tech development decisions that will ultimately impact their farming lives.

1. Introduction

Responsible Research and Innovation (RRI) is a paradigm which has grown over the past decade to support the governance of science and innovation with the aim of making new technologies ethically acceptable, fair, sustainable and socially desirable and beneficial (Von Schomberg, 2013). Central to RRI, are four pillars considered important in the research and innovation process: anticipation (exploring possible impacts), inclusion (engaging diverse voices), reflexivity (fostering critical reflection of assumptions) and responsiveness (responding with meaningful action) (Macnaghten et al., 2014). Industry, government and funding agencies have championed the development of new innovations for agriculture in recent years, however, there are likely to be challenges balancing the priorities of various agricultural stakeholders as agricultural innovation systems digitalise (Fielke et al., 2020), seeing as research has signalled uneven impacts of new technologies across rural and farming communities (e.g. Fielke et al., 2020; Jakku et al., 2019; Regan, 2019; Van der Burg et al., 2019; Bronson, 2019; Klerkx et al., 2019; Fleming et al., 2018; Carolan, 2018; Rose et al., 2016). To overcome undesired or unintended impacts of digital technologies, RRI promotes the active inclusion of 'non-traditional' diverse actors, including farmers and local communities, in the development of new farming technologies, as opposed to developing innovation based on decisions made by scientists and designers (Rose and Chilvers, 2018; Eastwood et al., 2017). Bronson (2019) argued that decisions made by scientists and designers in the design phase of an innovation can impact on future adoption rates. This raises an important question on whether designers and software developers, to date, have considered or reflected on what a new innovation is capable of doing, ought to do and for whom, during the innovation process itself? Steinke et al. (2020) also argued that pushing certain technologies, rather than responding to the particular communication challenges of potential users has led to the eventual failure of many new agro-advisory initiatives. Bronson (2019) and others in this field (e.g. Rose and Chilvers, 2018) have suggested that further academic efforts should more actively engage designers and engineers with end-users in research processes pertaining to agricultural innovation so that they are reasonably well positioned to reflect on the purposes of digital farming innovations, as they are taking shape.

1.1. Co-design approach

In addition to the arguments on RRI, both the European Union (EU) and the World Bank (see EU SCAR, 2012, 2014; World Bank, 2012) have long stressed that farmers' needs are not sufficiently addressed during innovation generation, and hence innovations are not relevant to them. It is now more widely understood that agricultural innovation needs to address and accommodate complex socio-scientific problems by mobilising a range of stakeholders who can offer multiple perspectives (Rose et al., 2020; Jakku and Thorburn, 2010). The nature and extent of stakeholder participation in agricultural research varies. It can cut across multiple actors to provide holistic views of problems (Turner et al., 2016); have a strategic, rather than a complete representation of stakeholders, based on their relative levels of interest, influence and/or benefit (Reed, 2008); or include a limited group of actors only (Dogliotti et al., 2014). Furthermore, a multitude of participatory methods and frameworks exist which seek to integrate various types of stakeholder interests and knowledge in innovation and to elucidate and co-solve problems (Berthet et al., 2018, 2016; Jakku and Thorburn, 2010). As such, it is important for researchers to explicitly delineate the nature and level of stakeholder participation in projects aimed at developing new digital communication technologies.

Co-design involves heterogeneous stakeholders in the collective exploration of solutions to a common problem and generally seeks to build and maintain a shared conception of the design problem to allow collaboration (Gardien et al., 2014; Barcellini et al., 2015). Furthermore, co-design provides an opportunity to explore and reflect upon the local needs and concerns of each respective stakeholder, thus, subsequently improving innovation design and delivery and the likelihood of implementation success (Khalid, 2006). This diversity and inclusiveness is one of the dimensions of RRI, which prioritises the involvement of stakeholders (Fossum et al., 2019). Through the co-design process, these stakeholders are involved in each step, from the initial conception of the product to the design and testing phases. Few empirical studies (Ayre et al., 2019; Lazzaro et al., 2018) have outlined, in methodological detail, the steps taken to successfully implement a co-design approach, which engages multiple stakeholders, in designing new digital communication technologies. This paper thus draws on analysis of activities in a Work Package (Use Case 4a, WP2) of the H2020 European NIVA project, which employed a design thinking methodology (Brown, 2008) to facilitate a bottom-up process for inclusion of stakeholder innovation knowledge, needs and solutions, respectively, in designing a novel geotag photo application. The current paper builds on recent work published by Kenny & Regan (2021) which examined the factors that influence Irish farmers' engagement with new smartphone apps and the supports required by farmers to successfully engage with smartphone apps for agriculture use. Further contributions to this body of work are made in the current paper by demonstrating how both researchers and technology developers engaged with a variety of stakeholders from the farming community to co-develop an agricultural app.

1.2. Design thinking

Multiple models of design thinking have emerged over the years, however, the roots of the approach date back to Professor John Arnold (1913–1963) who was famous for making his engineering students at MIT imagine that they were designing products for someone from outer space instead of for their peers (who always liked their design). In 1957, Arnold went to Stanford University where he built up the engineering design school. One of his students, David Kelley, later founded the now world leading design firm IDEO, as well as the D.school at Stanford University. Kelley's Stanford model of Design Thinking consists of 5 key phases: (i) Empathise; (ii) Define; (iii) Ideate; (iv) Prototype and (v) Test (Kelley, 2001). The first three phases will represent the focus of the current paper, up to the point of first prototype development of the

technology. These are the most pivotal stages of the design process in which the technology is created and defined, and where the unique value of multi-actor engagement is established. The first phase, *empathise,* focuses on gaining an understanding of users' needs and challenges through interviews and/or observation. Gaining insight into a user's emotions, aspirations, and fears can provide designers with critical cues and inspiration to create a more balanced and functional product, which meets the users' needs. Empathising with stakeholders from various backgrounds with different views and ideas on a new product helps to anticipate user needs and potential barriers to success at an early stage. Anticipation, a key pillar of the RRI framework, encourages similar exploration of possible impacts and risks at an early stage of development (Inigo and Blok, 2019). The second phase of design thinking helps to *define* the problem so that the project team and users can come up with solutions and ideas in the next phase, ideation. During the define phase of design thinking, it is important to use the data that was collected in *empathise* and to frame the issues and problems in a way that will promote problem solving in the next phase. In the RRI framework, reflexivity relates to this process of framing questions, while being aware of assumptions or bias (Zwart et al., 2014). Ideation is the mode of the design process which concentrates on idea generation. Ideation provides both the fuel and also the source material for building prototypes and getting innovative solutions into the hands of end users. *Prototyping,* the next phase of DT, advances the ideas into building artifacts and allows the design team to quickly make mistakes or encounter discoveries, while the final phase, *testing*, focuses on refining the prototype until an ideal solution is achieved for the problem being addressed (Henriksen et al., 2017).

Design thinking, however, should not be understood only as a process, but rather as a philosophy, which according to Baeck and Gremett (2012) could be characterised by nine key attributes, including: ambiguity, collaboration, constructiveness, curiosity, empathy, holism, iteration, non-judgement and openness. Overall, such attributes allow researchers to be comfortable in unclear situations, collaborate and problem-solve across an interdisciplinary team, foster non-judgmental and open communication between and with other stakeholders, become curious about and gain empathy for the end users' needs, and holistically attempt to find a solution to their problems. Emulating the RRI principle of reflexivity, design thinking represents an innovative, human-centered approach to problem-solving, which allows teams to step away from immediate and reactionary approaches to complex problems in favour of novel, broader approaches (Brown, 2008). The primary objective in this approach is to keep the needs, desires, and behaviours of all stakeholders in the ecosystem at the centre of the design process. Design thinking creates more extensive, more diverse, and more productive teams in which each member is invested in the changes being designed and proposed. The continuous process of planning, acting, reflecting and readjustment, offered by design thinking, allows researchers and innovation developers to continuously adapt in response to users' issues and solutions that emerge over time, echoing the principles embodied also by RRI (Klerkx et al., 2012). A particularly beneficial component of design thinking is that it allows researchers and end users to collaborate through framing problems and test solutions, using participatory processes (Schafer & Kroger, 2016). This critical level of engagement is akin to the principle of inclusion within RRI. The output represents a co-evolved technology with relevance to the respective settings of each end user. Design thinking has been used across many sectors to solve complex problems, with many studies pointing to its success. With respect to education, it has been found to enhance student engagement and achievement (Lin et al., 2020) as well as teachers level of teaching satisfaction (Crites and Rye, 2020), and in healthcare, studies report that design thinking has potential to help foster creativity and empathy in nursing students as they explore the human experience (Beaird et al., 2018). Design oriented work (e.g. participatory design, user-centered design, co-design) has also been successfully used in the agricultural literature (see Berthet et al., 2018 for an overview), including the redesign of dairying in New Zealand (Romera et al., 2020), an exploration of what role digital technology will play in the future of Australian agriculture (Fleming et al., 2021) and examination of farmers' transition processes towards more sustainable farming in Denmark (Aare et al., 2021). Given its ability to tangibly integrate key RRI pillars into the development process, the current study aimed to adopt design thinking design thinking as a research approach to co-design a geotag photo app, for use on smart devices.

1.3. Study context

The overall aim of the H2020 NIVA project[i] is to modernise IACS (Integrated Administration and Control System) by making efficient use of digital solutions and e-tools, by creating reliable methodologies and harmonised data sets for monitoring agricultural performance, while reducing administrative burdens for farmers, paying agencies and other stakeholders. In Use Case 4a, an interdisciplinary, multi-actor team of social scientists, software developers, and government stakeholders were responsible for co-developing, with agricultural stakeholders, a smartphone application (app) that will be used to resolve payment claim queries with the paying agency responsible for monitoring and inspecting farming activity, under the Common Agricultural Policy. In the event of supporting evidence being needed to process a payment claim, farmers and their advisors will be able to use this smartphone app to take a geotagged photo of the land parcel in question and submit the evidence directly to the paying agency. Adoption of this app will reduce the need for on-the-ground farm inspections and accelerate claim processing, offering significant benefits to both claimants and paying agency administrators. The current process in place requires farmers to submit supporting paperwork to resolve payment claim queries via the general post to the paying agency for acceptance or rejection. If rejected, a farm inspector may be sent out to the farmers land to conduct an on-the-ground farm inspection. With the geotagged photo app however, the incentive for the farmer may be a reduced chance of an on-the-spot farm inspection, if they upload the photographic evidence of agricultural activity (e.g. number of animals grazing on the land) or clarify the query with the paying agency. The initial phase of development and testing of the geotagged photo app focuses on the Irish farming community and stakeholders; subsequent work is scheduled for further research and development in other participating countries.

Problem analysis occurred at the proposal stage of the EU H2020 tendering process. Governmental actors leading the proposal engaged with EU member state partners and policymakers to define the problem and a suggested technology solution. The problem was defined as: "an innovation is needed to improve communications between farmers and farm inspectors". The starting point for the solution was bound by the parameters set out by the funding body; as the call was focused specifically on *digitalisation CAP governance,* the team had to work within the parameters of technological innovations. From here, the proposal team engaged with potential end users to brainstorm possible technological innovations which led to the geo-tagged photo app being identified as a solution which could be brought forward for further development.

The end goal of our design thinking approach is to develop a customisable app for real-time data flows between system users, i.e., farmers/advisors to respective governing bodies, facilitating improved communication relating to agricultural queries. In this paper, we describe how our design thinking approach was implemented to ensure end-users from the agricultural community were involved in the core design process of the geotag photo app. We also present and discuss the results obtained from the design thinking approach employed and indicate how the app will be further developed through subsequent stages of the design thinking process. As such, this paper offers the opportunity to examine the factors shaping the process of design thinking in a research project by specifically asking: (i) how can researchers and IT designers ensure that farmers and other agricultural stakeholders partake in the development of new digital communication technologies?

(ii) what insights does the process of bringing multiple stakeholders together in designing new innovations bring? and (iii) what is the value of using a design thinking approach in developing new digital communication technologies? In addressing these questions the paper aims to contribute to the theoretical development of design thinking as a methodology for digital agriculture, in particular with respect to how design thinking is enacted by different agents in a research project, which has been under-developed to date. It is especially pertinent to pause and critically assess the process from an RRI perspective in order to demonstrate the relative merit of a design thinking approach in agricultural research.

2. Methods

The study design was inspired by the Stanford design thinking process (Doorley et al., 2018). Table 1 provides a summary of the approach taken at each of the three phases; in practice, these phases overlap and iterate, however the methodologies set out below offer an insight as to how the principles and ethos of these phases can be operationally and practically realised during technology design. The following section aims to explicitly outline how we conducted the first three phases of our design thinking approach. (See Figs. 1 and 2.)

2.1. Phase 1: empathise

The first stage, *empathise,* focused on gaining an empathic understanding of users' needs and challenges. A number of activities were employed at this initial stage. A substantial amount of information was gathered at this stage to use during the next stage of the design process and develop the best possible understanding of the users: what is meaningful to them; how they think of the world; their needs; and the problems that underlie the development of the particular product under consideration. The theory of this phase is that the problems of the users are not often related to the designers and thus designers need to empathise with the users to design appropriate solutions that fit their needs. The below activities were employed in this research project to empathise with each respective stakeholder, as part of the design thinking approach.

2.1.1. Stakeholder mapping

During October 2019, a stakeholder mapping exercise was conducted with 20 stakeholders. This included Technology Developers (n = 2), Government Civil Service (n = 10), Farm Advisors (n = 6) and Farming Organisations (n = 2). At the outset, the stakeholder mapping process was explained to each participant and consent was sought for audio recording. Participants were asked to consider (i) what type(s) of stakeholder a geotag photo app might impact; (ii) the manner in which the new app would influence their work; and (iii) what role they would play with regards to the new app, once it is rolled out. Subsequently, participants were asked to review all stakeholders mentioned; consider whether they were happy with each one (or whether they felt anyone was missing); and lastly were asked to categorise them, into their respective groups, if deemed relevant and possible.

2.1.2. Key informant interviews

From October–November 2019, 18 interviews were conducted with technology developers, government actors, private and public farm advisors, and representatives from farming organisations to gain an understanding of needs and concerns from a wide variety of perspectives. Purposive and snowball sampling was used to recruit stakeholders for the interviews; which took place in person or by telephone. In developing the proposed interview schedule, the researcher followed Turner III's (2010) guide on effective research questioning (*see appendix A for list of interview questions*). Interview data were transcribed verbatim

Table 1
Range of participating stakeholders and types of data generated in all 3 phases of the Design Thinking Approach.

Three phases	Action	Actors involved	Aim	N	Method	Data	RRI
Phase 1 - *Empathise*	Stakeholder mapping	Technology Developers Government Actors Private and Public Farm Advisors Farming Organisations	To identify the stakeholders likely to be interested in or impacted by the technology	20	Dialogue Visual	Audio-recordings Notes	*Anticipation* *Inclusion*
	Individual interviews	Technology Developers Government Actors Private and Public Farm Advisors	To identify and gain an understanding of needs and concerns from different perspectives	18	Semi-structured interviews	Verbatim transcriptions	
	Focus Groups	Farmers	To identify farmers' needs and concerns related to digital technologies and specifically, smartphones and agricultural apps; Explore what barriers and facilitators influence farmers' engagement with newly developed agricultural-related apps	41	Semi-structured focus groups	Verbatim transcriptions	
Phase 2 - *Define*	Reflection of phase 1 findings	Social and Behavioural scientists Technology Developers Government actors	To examine what patterns exist/are apparent? To identify what is the big user problem that needs to be solved? To reframe the challenge reflecting learnings from stakeholder inclusion activities in preceding phase	6	Development of 'Problem statements' Development of 'User personas'	Summarised Phase 1 findings with reflections	*Reflexivity*
Phase 3 - *Ideation*	User Workshops	Farmers Public Farm Advisors Farm Inspectors NIVA project partners	To validate the results from phase 1 and 2 To co-create, generate, discuss and refine ideas To prioritise the ideas with the participants	73	'Vision Board' exercise 'User Needs' exercise 'Crazy 8's' exercise	Audio Recordings Flipchart content Sticky Dot Voting Photographs	*Anticipation* *Inclusion* *Reflexivity*

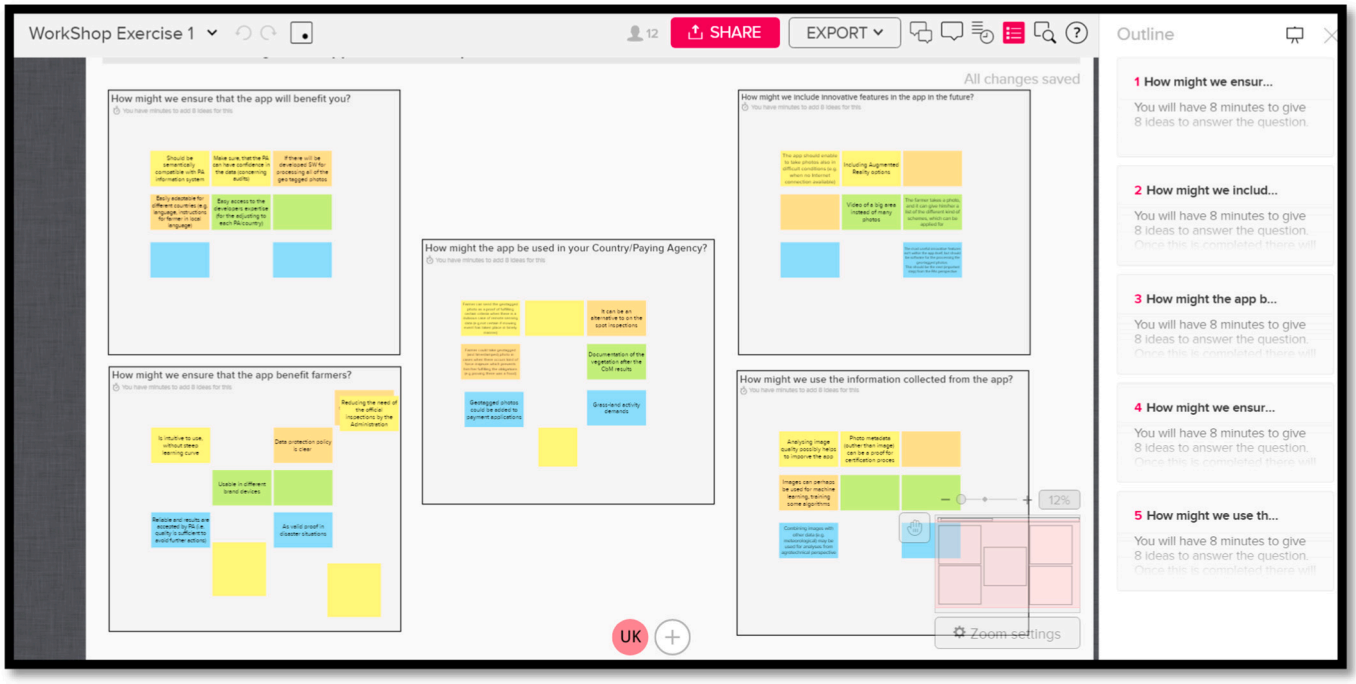


Fig. 1. Virtual Crazy 8's with NIVA project partners.

and personal identifiers, such as names, were removed from the transcripts to protect participants' confidentiality. Post transcription, two of the researchers (first and last) thematically analysed the data using an inductive approach in accordance with the guidelines developed by Braun and Clarke (2014). Thematic analysis is a method of identifying, analysing, interpreting, and reporting patterns and themes within qualitative data (Braun & Clarke, 2014). A total of 11 themes emerged.

2.1.3. *Farmer focus groups*

A total of 41 farmers, consisting of 37 men and 4 women participated in 7 focus groups conducted across four regions in the Republic of Ireland (For more details on this stage of data collection and an in-depth analysis of the results, see [anonymised]). The focus groups took place during October–December 2019. Focus group questions were developed by the multidisciplinary research team with an aim to explore farmers' needs and concerns related to digital technologies and the barriers and facilitators that farmers' perceive to influence their engagement with digital technologies, in particular – smartphones and apps. A structured interview schedule was used to guide the focus group discussions. The questioning sequence (inspired by Krueger and Casey's (2014) recommendations) commenced with an introductory question, which served to facilitate open and free dialogue among participants. Once comfortable with the topic and settled into the discussion, a number of introductory, transitional, key, and closing questions were asked of the participants. Immediately after each of the focus groups, the researcher compiled descriptive summaries of the group discussions, to capture instant impressions of the group content. Focus group data were transcribed verbatim and anonymised to protect participants' confidentiality. Post transcription, the first and last researcher also used an inductive thematic approach (Braun & Clarke, 2012) to analyse the data (see [anonymised] for more detail on the analytical process of our focus group work). A total of seven overarching themes and thirteen subthemes emerged from the data (see Kenny & Regan, 2021) for more detail on breakdown of themes).

2.2. *Phase 2: define*

The second stage in our design thinking process was dedicated to '*defining*' the problem. The technical 'definition' of the problem at the outset of this effort was summarised as follows: "Common Agricultural Policy (CAP) payments processing is linked to approval of farmer claims. The process of gathering evidence to support a claim can be resource intensive, possibly requiring a departmental inspection visit and could result in delayed payments. The app must contain anti-spoofing components and expedite the process for the department, farmers and their representatives." In order to address this problem, the define phase aimed to explore a variety of stakeholders views on a solution: "the use of a geotagged photo app, which will enable farmers to receive notification requests, take a photo of a land parcel and submit it to the department to resolve queries and solve claims".

This phase took place during January and February, and comprised desk and group work of the core development team (comprised of government actors, technology developers and social and behavioural scientists). All findings from the *'empathise phase'* were collated and questioning and reflection of the data was carried out. Questions, such as (i) "what difficulties and barriers are the users currently coming up against?" and (ii) "what is the big user problem that needs to be solved?" were routinely used in this phase to make further sense of the data collected in Phase 1 [ii]. A range of design thinking exercises were used to support this process. In particular, extending and reframing the interview and focus group data into 'problem statements', 'how might we…?' questions, and 'user personas' – reflective exercises recommended for this phase, was conducted. In order to begin with developing problem statements, the first and last researcher re-examined the interview and focus group themes developed in the empathy phase, and explored what 'problems' emerged from each. Based on the identified 'problems', both researchers synthesised and selected a set of user needs and circulated them to the wider research team for examination. The team convened and together developed a list of actionable problem statements which were subsequently re-shaped into 'how might we…?' questions in order to focus the problems towards a solutions orientation. The list of 'how might we…?' questions flowed directly from the problem statements. The 'how might we….?' questions represented subsets of the entire problem, focusing on different aspects of the design challenge. The 'how might we questions…?' were used in the workshops to support workshop participants (end-users) in identifying the practical steps towards

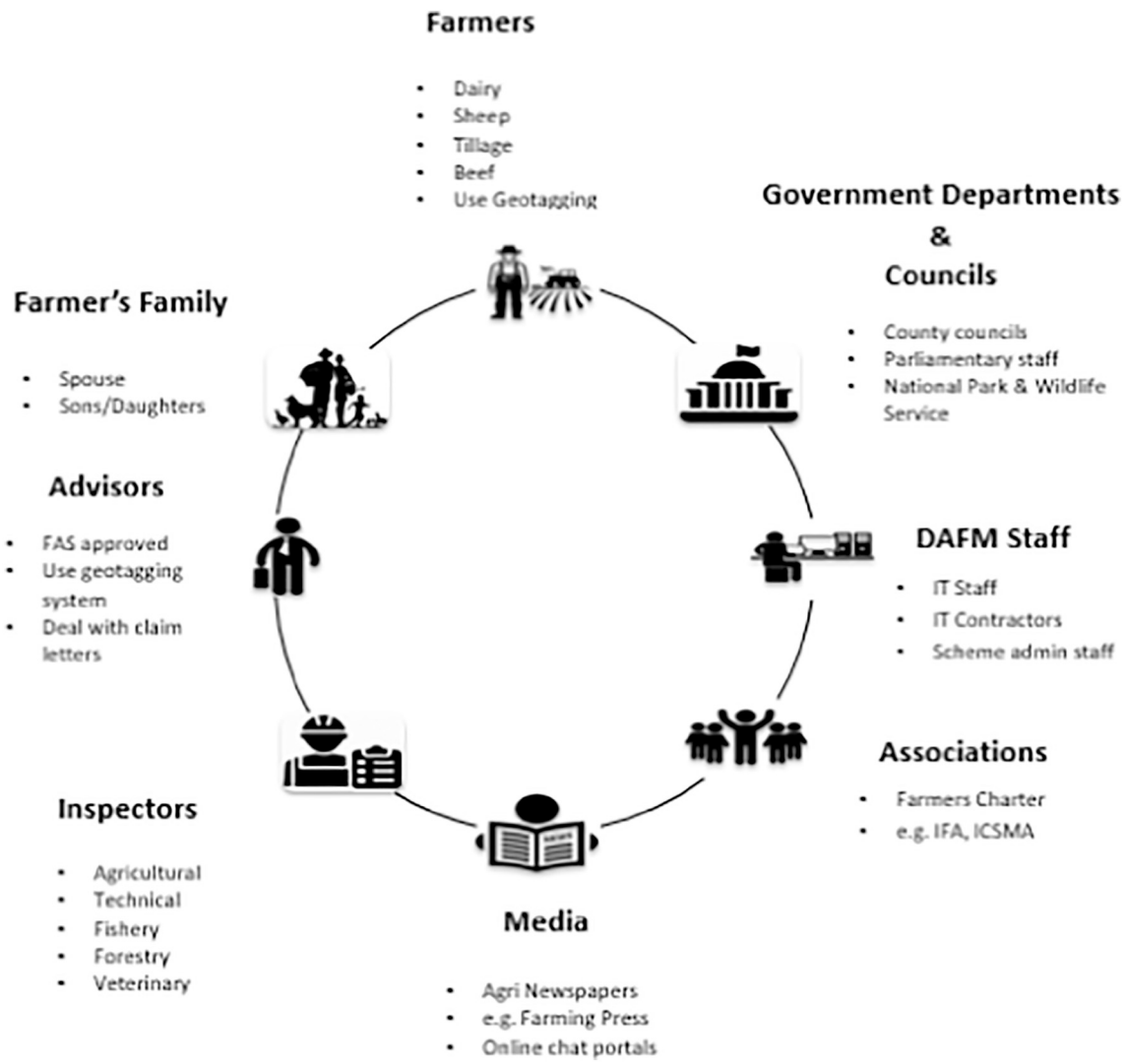


Fig. 2. Stakeholder Mapping.

implementation of the app and develop solutions to the problems previously identified in the earlier phase, empathise. Table 2 shows examples of the actionable problem statements, which were converted into a range of 'how might we….?' *questions*. The full list is provided in *Appendix B*.

A frequently used design thinking exercise, *'user personas'*, were also developed in phase 2 which reflected a hypothetical archetype of a real user, describing a users' goals, and digital barriers and facilitators. The personas were created based on a synthesis of what we had learned about our real users in phase 1 (empathise) and the themes or characteristics we observed that many of them shared in common. In order to 'humanise' the personas (which would later be used in Phase 3), arbitrary details on their characteristics, such as, name (pseudonyms used in all cases), occupation, sex, and age, were also included. The personas developed in this phase were represented in textual form, enriched by a photo (*see appendix C for all personas developed*) and were used in the ideation phase to test how valid the problems for each respective persona were, with a separate set of end-users. The use of such personas in the user workshops generated additional insights of our end users' needs, experiences and behaviours, with respect to use of the geotagged photo app given that RI scholars advance the position that technologies and society are mutually shaped; in that norms and values are not something that can be taken out of the production of technologies (Bronson, 2019; Rose and Chilvers, 2018; Guston, 2014).

2.3. Phase 3: ideate

The third stage in the design thinking process was dedicated to ideation. Specifically this phase provided an opportunity to: (i) step beyond obvious solutions and thus increase the innovation potential of the project solution set; (ii) harness the collective perspectives and strengths of the project teams; (iii) enlist end-users to co-design solutions to the key challenges (iv) uncover unexpected areas of exploration; and (v) drive the team beyond obvious solutions.

2.3.1. User workshops

Four user workshops (one physical and three virtual[iii]) were carried out. A purposive sampling strategy was used to recruit farmers and advisors from different geographic regions, with particular focus given on ensuring representation from regions which may have a higher likelihood of needing to address queries via a geo-tag imagery app due to the landscape and physical environment in which they are farming. User Workshop 1 took place in February 2020 in a face-to-face setting with 20 participants, including farmers, farm advisors and farm inspectors; participants came from the midlands region of Ireland. User Workshop 2 was conducted online in May 2020 with 9 participants representing members of a young farmers' organisation from different regions of Ireland. User Workshop 3 took place in May 2020, online, with 12 participants, including farmers and advisors; participants came from the

Table 2
Examples of Problem Statements and "How might we…? Questions based on User inputs from phase 1 of the Design thinking approach (farmer focus groups).

Findings from Farmer Focus Groups	Problem Statements	"How Might We…?" Questions
Theme 1: Farmers' General Attitudes towards Smartphones and Apps	Older farmers are not interested in using smartphones for work than younger farmers	➢ How might we promote interest among older farmers to use smartphones for work?
Theme 2: Value Propositions	Farmers feel that smartphone apps enable them to live a better quality of life, and run a more profitable and efficient farm	➢ How might we show farmers that smartphones are useful for work?
Theme 3: Self-Efficacy	Farmers from certain farming sectors are more capable of using a smartphone (for work)	How might we help farmers to become more confident in their ability to use a smartphone?
Theme 4: Accessibility	Farmers living in areas of poor internet connection will not use the app	➢ How might we overcome internet connection issues for farmers so that they can use the app?
Theme 5: Socio-cultural Beliefs	Departmental monitoring of farmers and their farming activity will increase as a result of the app	➢ How might we overcome concerns that the app will allow the Department to monitor everything the farmer is doing?
Theme 6: Keys to success	Failure to impress users at the stage of launch will lead to a sense of distrust in the app	➢ How might we successfully design the app for farmers so that it is easy to use and no errors arise?
Theme 7: Digital Divide	There is a risk that farmers who will not be able to use the app will feel isolated and left behind	➢ How might we ensure that farmers who will not be able to use the app will not feel isolated and left behind?

north-west region of Ireland. Given the ambition for the app to be extended eventually to other European countries, a final workshop was conducted in June 2020 virtually with 32 dispersed EU NIVA project partners; this workshop included partners from the different countries' Paying Agencies. These Paying Agencies support schemes under the Common Agricultural Policy. The next section outlines the various activities[ii] conducted in both the face-to-face and virtual workshops.

2.4. Physical, face-to-face workshop

2.4.1. Vision board

A vision board activity was firstly conducted with participants attending the face-to-face workshop. This is a useful exercise to investigate participants' current mood and feelings around the issue at hand. In the case of this project, the vision board was used to seek both farmers' and advisors' views on the current Common Agricultural Policy process and communication with department staff when applying for grants. Participants were divided into 4 groups of 5 and each group was given 5 min to pick as many words or phrases to describe their current feelings. Such thoughts and feelings were labelled ***'The Past'*** in order to move participants into the mind frame of *change* and to think about the problems the research team were trying to creatively solve. Group members were subsequently asked to focus on ***'The future'*** vision of the process; to describe the process from a new perspective, with the current process being replaced with the introduction of a geotagged photo app. This exercise gave the research team a clear picture of the current landscape and how all stakeholders would like the process to be perceived in the future.

2.4.2. User needs

The second activity conducted in the face-to-face workshop involved a user needs task. Each group was given 2 of the user personas (*Appendix C*) developed based on the findings from the preceding design thinking phases. A total of 15 min per persona was given to each group to examine and discuss the needs from that user personas' point of view and a final 15 min to discuss additional needs that they feel may arise (personal or inherited ideas from the group) for that persona. Once complete, the groups voted on the most important persona needs using a 'green dot' method; which involved using 3 dots each to signify the needs that they felt were of most importance to them.

2.4.3. Ideation: Crazy 8's

Ideation is the creative process of generating, developing and the communicating new ideas. To facilitate the ideation session, a process called Crazy 8 s was employed; a technique developed by Google to structure idea generation workshops. Each team was given 5 'How might we…?' questions devised from the preceding design thinking phases (see Table 3 and *Appendix B*) and were encouraged to give 8 solutions to each question in 8 min. The group were then given 3 green dots to vote on their favourite answers. The rules for this activity were as follows: (i) Quantity over Quality: This helps to ensure that each person within the group tries to generate 8 ideas; (ii) Focus on one 'How might we…?' question at a time; (iii) No mobile devices allowed and (iv) Conversation is encouraged between teams.

2.5. Virtual workshops

The virtual workshops differed with respect to some of the activities conducted in the face-to-face workshop. The virtual workshops took place on two platforms using specialised software: namely, MURAL[iv] and Zoom[v]. MURAL, a specialised software for online collaboration, was selected as the most ideal platform for the workshops as it (i) allows for multiple boards to be used by participants and multiple users to participate at once; (ii) it parallels the 'real-life environment' from workshop 1 and (iii) follows the same principles as the face to face workshop with respect to sticky notes and voting polls. The second platform, Zoom, was considered an ideal conversational virtual setting, as it (i) can be used simultaneously with MURAL; (ii) allows for multiple users at a time; (iii) has an audio-recording capacity and (iv) can host breakout sessions (groups of 5–10 people), which was ideal for our small group activities. Prior to the commencement of each workshop, the project team stated that the session would be audio recorded and a PowerPoint presentation was delivered to the participants which outlined the context of NIVA, what UC4a aimed to achieve, how the online platform could be accessed and subsequently how it could be used for the purposes of the workshop activities. Below details the types of activities conducted on MURAL, with one overlapping activity (Crazy 8's) between both the virtual and face-to-face workshop.

2.5.1. Warm up activities

Participants were firstly asked to select 'Board 1' when they logged on to MURAL. On this board, they were presented with a map of Ireland or Europe (the latter for the wider NIVA project partner workshop) entitled: "Where are you?". Each participant was asked to write their name on a label and drop it on their hometown or country. This exercise helped familiarise participants with the functionalities of MURAL. As a second warm-up activity, participants were asked to consider the benefits of digital technology in the agricultural sector, in order to promote a group discussion among participants. Participants were asked to insert their thoughts on a coloured sticky note found in board 2.

2.5.2. Ideation: Crazy 8's

Following the warm-up activities in which participants had by then become better acquainted with the software, participants were directed to the primary online workshop activity which included 5 separate

Table 3
Summary of findings from user co-design workshops.

User workshops	How might we questions	Solutions
	How might we design an app that farmers agree is easy to use?	Easy to access and navigate Visual/colourful Submission with save feature Contact/helpline Simple login (face/finger) Offline options
	How might we provide assurance to farmers that their application will be processed on time?	Tacking and Status updates Traffic light system for status Verification text
	How might we ensure that the photo taken with a smartphone camera adequately captures the issue under query?	Clear instructions and action buttons User Friendly Support option Good visual interface Show advisors how to use it first Long lead-in time between launch and use
	How might we overcome data protection issues that could be associated with using the app?	Secure Log in No personal data or personas in photos Photo only used for purpose of request Request is only visible to farmer/agent
	How might we tackle the concern of farmers self-implicating themselves when submitting geo-tagged photos via the app?	Requests are only used to validate a claim Good communication
	How might we encourage and build trust between inspectors and farmers/farm advisors when it comes to submitting photos?	Dedicated Helpline Confidentiality Positive user experience
	How might we ensure the app improves communications between the farmer and the Department?	Interactive screen share Chat bot FAQ section Quick response (timed metric) Timeline on your query under review
	How might we ensure that all Farmers will be able to understand what the app is for?	Push notifications for deadlines Step by step tutorial/ instructions while taking pictures Photo quality guidelines Explanation of issue to be resolved Sample pictures

question boards of 'How might we…?' questions, similar to the face-to-face workshop. Fewer questions (5 as opposed to 8 in comparison with the face–to–face workshop) were asked in the virtual workshops due to stricter time constraints. There was also a consensus between project members that more than 5 questions may risk participant disengagement due to a lack of face-to-face contact. The 'How might we…?' question was outlined at the top of the board and sticky notes were placed within the board to facilitate participant's answers. For this activity, if the overall group size was large enough (more than 10 participants), the facilitator created 'break out' rooms on Zoom (n = ~5 per break out room) to allow for a conducive setting for group work. Once the timer (5 min per question) ended, all 'break out' rooms were ended and participants guided back to the shared Zoom space. Each participant was asked to place three sticky dots on the ideas generated, that they felt were of most importance to them, for each 'How might we…?' question. Participants were permitted to place 3 sticky dots on one idea only, or were entitled to spread them out across three ideas. A two minute timer was in place for each voting session.

3. Results and reflections

In this section the collective insights garnered from the first three phases of the design thinking approach for this project, which helped to shape the design and development of the geotagged photo app, are presented. Reflections on how design thinking enabled a more responsible and responsive technology design process are also highlighted.

3.1. Theme 1: the technology-stakeholder ecosystem

At the outset of the technology design process, the farmer was assumed to be the key end-user for the current technology. However, findings throughout the process, and particularly elucidated in the stakeholder mapping activity, highlighted that a number of target end-users of the technology and a number of key supporting stakeholders who will play an important role in supporting end-users to adopt the geotag smartphone app. In total, four categories of end-users emerged from the stakeholder map, including: (i) Farmers; (ii) Farmers' Families/ Neighbours (spouses, children, nieces/nephews, peers); (iii) Inspectors and (iv) Advisors; whilst a total of five supporting agents, including (i) Farming Organisations; (ii) DAFM (Paying Agency) staff; (iii) Advisors; (iv) Media outlets and (v) Government Departments and Councils were identified. Advisors were perceived to have a dual role in supporting farmers to adopt the app and become a likely end-user of the technology itself.

With respect to the distinct *farmer groups* mentioned, participants felt that dairy and tillage farmers would adapt positively to the new app, given their reputation of being a particularly progressive group of farmers, who have adapted well to new technologies in the past and who have distinct land cover (tillage, specifically). Participants also felt that beef and sheep farmers would positively benefit from the technology given that it will reduce their rate of farm inspections, especially in the case of sheep farmers', whose land parcels' are often subject to an inspection due to the rural nature of the land. Perceptions that farmers' spouses, children, relatives and/or neighbours may become an inadvertent end-user of the technology were also expressed. Some mentioned that a majority of the farm administrative work is conducted by farmers' spouses and thus they will likely become responsible for submitting the geotagging imagery to the Department, via the new app, once it is rolled out. Similarly, others mentioned that farmers will rely on their children or neighbours to submit the geotagged imagery to the Department on their behalf, should they not feel confident in fulfilling the task by themselves.

Advisors were also considered a key end-user and a stakeholder whom the new technology would positively impact, due to its ability to deal with customer claims in a more efficient manner. Likewise, the interviewees felt that *inspectors* will become likely end-users of the new app and will welcome the new technology, as it will serve to reduce the number of farm inspections required of them. They also felt that it would impact their role as they will be responsible for examining the back end system of the app with regards to the submitted geotagged imagery. The *media* and *farming unions* were also deemed important sources of influence and potential support, as many felt that positive reviews on the new technology, published in such media outlets/endorsed by farming unions, would enhance farmers' trust of the technology and would enhance user buy in. Additionally, it was mentioned by some participants that farmers may approach their local government officials regarding their concerns with the geotagging app; thus, similar to family members/neighbours, may become an inadvertent source of support to such farmer cases. Lastly, the informants outlined that the new technology will influence the role and responsibilities of governmental *IT staff* whom currently deal with and support farmers with their claims

concerns.

3.1.1. Process reflection

According to Hendricks et al. (2018), if design thinking is going to be used as an approach to design and implement effective, equitable and sustainable solutions, stakeholder participation should be integrated into the process. There is also a growing recognition among scholars that responsible innovation should not just welcome diversity, it should nurture it (Stilgoe et al., 2013); views that were acted on at the beginning of this project by engaging multiple actors throughout the process and also specifically engaging them in a stakeholder mapping activity at an early stage of the process. During this initial activity, a wide view of stakeholders who could be interested in and impacted by the technology was obtained, extending to the formal roles of advisors and inspectors, as well as informal support systems, such as farmer's families and neighbours. The multi-stakeholder perspective embedded throughout the process helped us to develop a more complete anticipation of (1) the identity of the end-user(s) and (2) their diverse aspirations, values, fears and needs, from the outset of the project. The composition of focus groups and workshops was responsive to the stakeholder mapping exercise and designed to ensure representation from all of the primary identified cohorts, thereby enabling an extensive understanding of respective needs and perspectives of these stakeholders.

At the outset of the technology design process, the farmer was highlighted as the target end-user of the app; however, the design thinking process revealed a number of additional key target end-users not least of which was the farmer's 'nominee', often defined as the farm advisor or a relative. Reliance on the support of personal networks indicated potential lack of confidence with or even access to technology and signalled that many farmers are likely to 'sub-contract' the task out to a nominee. It also highlighted how certain professional obligations and roles may specifically change as a result of the technology (e.g. farm advisors, inspectorate staff). The mapping exercise revealed the need to extend stakeholder engagement to a diverse range of actors including farm advisors and inspectorate staff. While we recognised that all identified stakeholders could potentially impact the design outcome and/or technology adoption, our design thinking process aimed to prioritise the involvement of representatives from all the identified possible end-user groups (farmers, farm advisors and inspectorate staff) and a subset of the supporting stakeholders (farming organisations, government actors) coinciding with relative levels of benefit, influence and interest. Notwithstanding, considerations regarding the other identified stakeholder groups (e.g. media outlets, government departments & councils) will come to the fore as the product emerges from the design thinking process particularly in later prototyping stages.

3.2. Theme 2: multi-stakeholder narratives

The design thinking process revealed that farm advisors and farming organisations are open to the introduction of the proposed app, on the basis that (i) farmers' current rights are maintained; (ii) farmers and advisors are adequately trained and supported in making a transition to the app; (iii) farmers are empowered by using the app and are guaranteed their payments; (iv) farmers who do not use technology are not left behind and (v) that the newly developed app will be easy to use for all farmers. Mixed views were expressed by advisors with respect to their own personal workloads; some felt that the new geotag photo activity will result in an increased personal workload as many farmers would rely on advisors to conduct the task on their behalf, whereas others outlined that an online application process is 'instant' and will help to 'speed things up' and 'make their life easier' with respect to obtaining farmers' payments. Some of the stakeholders were less convinced about the introduction of a geotag photo app as they felt it would mostly benefit the Department. These advantages included: (i) a reduction in administrative and on-the-ground work for inspectors; (ii) simplification of CAP; (iii) a reduction in paperwork, by making the process of monitoring self-regulatory; (iv) an enhanced ability to monitor poor land; and (v) an enhanced feeling of satisfaction that the Department are progressing well with respect to creating an agri-tech environment. Barriers to adoption were also raised by many of the participants including age (older farmers will not be able to use the app), fear (fear of getting caught for over claims on farm, as they would have been able to hide things up until now; fear of submitting wrong photo; and fears about interacting with the Department), and internet access (a lack of internet connectivity might be an issue for some rural areas). Some of the below sample quotes highlight the views of advisors and farming organisations on the introduction of the geotag photo app:

"A farmer might be nervous of being asked to supply photos right because in practical terms he would need to know or he might feel that he needs to know what are my rights here, right, what are the implications of being asked to send a photo. If I send the wrong photo, if I don't send enough photos, if I send a photo that doesn't look good enough or if the quality of it in terms of pixilation or whatever isn't good enough, you know there are areas there. So a farmer might be nervous to press send so to speak" (Farming Organisation, one-to-one interviews).

The design thinking process highlighted that some government staff, including the agricultural inspectorate, held positive perceptions about introducing a geotagging app; whilst others were against it. In particular, those who were positive about the app felt that it could empower farmers to take control of the overclaims process once they are adequately trained on how to use the app, could speed up payments made to farmers, would help to alleviate current communication confusions between the department and the farmer, would enable the department to deal with appeals more efficiently and would enable the farmer to learn more about the overclaims process. Informants who held less positive views felt that it would cause issues for older farmers who cannot use technology or for those without access to it, enable farmers and their advisors to submit manipulated imagery and will lead to confusion regarding the rights of the farmer in relation to data protection.

"You have third party data here and all, is there concerns around GDPR [General Data Protection Regulation] and if you have a family member or an agent, that's probably all going to have to be ironed out, does each family member, would they have to be registered as an agent with the department. That's something maybe that has to be looked at from data protection and GDPR point of view" (DAFM staff, one-to-one interviews).

There was also a sense of scepticism with regards to whether the new geotagging app will speed up payments for farmers. All of the advisors shared stories about the negative experiences they have had with the department with regards to previous geotagging activity, such as administrative delays and errors. Inspectors too were skeptical – feeling the app may undermine their work, or enable farmers to engage in manipulation of photos. Across both groups of stakeholders, there was a general consensus on the potential utility of the app for agricultural monitoring purposes, but challenges of trust, access, capability and age were seen as major barriers to adoption. Using a range of qualitative methodologies clearly helped to elicit the way multiple stakeholders feel and think about the proposed app *early* on in the developmental process. From the design thinking process, we also learned that farmers perceived a number of barriers for engaging with digital technologies which included low digital confidence and capability, fear, lack of trust, internet connectivity, prior poor experience with tech and a preference for traditional methods of farming. Some commonality of viewpoint regarding drivers also existed and these included stress reduction, improved communication with government bodies, time savings and a sense of empowerment (For a more detailed analysis of these farmers' views, see [anonymised]).

"Well we're doing fine, we are getting there without them (smartphones), how more can I explain that, why use an app when you can use a book, maybe I'm prehistoric in that way but, you can revert back to the book" (Farmer, focus groups).

The geotag app is intended to support the Basic Payment Scheme

(BPS) application process. Specifically, it is foreseen that the application can be used to support inspection related queries and to resolve application uncertainties. Currently, land eligibility is checked systematically by the department and 5% of applicants under all schemes under the BPS will be selected for inspection. The app has the potential to reduce the need for physical inspections and could thereby be viewed as a compliance tool. Indeed, some of the aforementioned stakeholder feedback reflects this perception that the app may primarily benefit the department. The design thinking exercises were carefully crafted to capture and reflect the concerns of all stakeholders but also to discover how the app could meaningfully benefit all stakeholders.

3.2.1. Process reflection

For the last three decades, institutions overseeing the governance of science and technology, such as the European Union (EU), have increasingly promoted RRI policies in order to achieve a better fit between science and engineering developments and socio-ethical concerns (Schot and Steinmueller, 2016a, 2016b). In particular, RRI prioritises the admission of 'new voices' into the science and innovation process (Genus and Stirling, 2018). As a multi-actor team, we engaged directly with and developed a genuine dialogue across a wide variety of stakeholders in order to become familiar with their worldviews and needs. In doing so, this allowed our development team to acknowledge our own areas of uncertainty and lack of expertise, particularly in experiential and tacit knowledge, with respect to the design problem. Similar to the RRI dimension of *anticipation*, we aimed to be anticipatory in the sense of exploring possibilities (not making predictions) and analysing intended and potentially unintended impacts that might arise, prior to the apps' development.

As design thinking is initially problem focused, feedback from heterogeneous stakeholders and user-groups (interviews and focus groups) was essential in identifying concerns that may need to be addressed later on in a solution. The design thinking process reinforced concern for the uneven impact of new technologies across farming and rural communities; as seen in other studies (e.g. Jakku et al., 2019; Regan, 2019). For example, it was felt that some farming sectors would be more willing than others to trial the app with participants highlighting that dairy and tillage farmers were a progressive group that have previously adapted well to new technologies. Similarly, age was identified as a key indicator relating to adoption. Therefore, it was important that the engagement we carried out with farmers as part of the design thinking process was as inclusive as possible of different farming sectors, different demographic profiles and different contexts (e.g. geography). This was achieved and led to much richer insights on the needs and concerns of farmers. A principle underscored in the RRI framework as a pivotal lever; the design thinking DT process enabled us to *engage* diverse voices to understand the problem from many different perspectives – and *before* technology development took place so that solutions could be built in to address issues arising.

The design thinking process also allowed us to embrace reflexivity and responsivity in the face of what we learned from the engagement with the different actors. Throughout the *empathise* phase, as our understanding of the needs, attitudes and motivations of stakeholders were developed, the challenge was reframed. The original challenge was to develop a geotagged photo app that will be accessible to and valued by all users. It could be argued that the pre-existing identification of a specific department sponsored technological solution is at odds with a responsive approach. This might be underlined by, for example, advisor concerns related to increased workload or some farmer scepticism regarding the usefulness of the app. Subsequent design thinking activities were pivotal to broadening the perspective of the project group. The *empathise and define* phases enabled the multi-actor development team to anticipate a much wider set of user needs, revealing multiple dimensions to the problem. Whereas the initial focus had primarily been on 'getting the *technology* right'; the technology challenge evolved as the early design thinking phases revealed broader issues that were at play including technological confidence, experience, socio-cultural beliefs, and access; issues which cannot be addressed by technology alone. On reflection, the team identified additional dimensions to the problem. The *trust* dimension must resolve issues related to transparency, control and fear of self-implication. In tangible terms for technology development, this suggests that app adoption will be dependent on features, such as visibility on claim progress and responsive in-app communications. However, actions outside of the development of the technology will need to take place also, including for example, ensuring access to technology and providing digital training. While a good understanding of 'what the app is capable of doing' was shared by the project team at the outset, the *empathise* stage highlighted that not all stakeholders are convinced of the utility or value of the app and there is a perception that the technology will benefit certain stakeholders but not others. This '*value*' dimension is ultimately part of the problem to be solved. Stakeholders' reservations were viewed as solutions in terms of ensuring that the app itself would not replace, but rather compliment, current processes; and these reservations will be further taken forward to consider other ways for improving communication between farmers and inspectors. Furthermore, the technology support actions will need to work to build a culture of trust through additional means whereby farmers value the app and are willing and happy to use it for compliance purposes.

Responsible innovation requires a capacity to change shape or direction in response to stakeholder values (Stilgoe et al., 2013). The inclusion of multiple stakeholder voices across the early stages of the design thinking process revealed meaningful insights into their feelings of fear towards and scepticism of the app; which required us to think about and adjust our course of action in the app development process. For example, farmers revealed their need to not feel that they are being increasingly monitored, surveilled and controlled via the app. Feelings of mistrust between farmers and the Department due to past negative experiences were also alluded to; a finding that corroborates prior literature (Agyekumhene et al., 2020; Trienekens, 2011). Skeptical views were also expressed by inspectors, on the authenticity of information/images provided by farmers; which showed us that for information to be effective in improving collaboration, its trustworthiness was crucial. This highlighted the need to counter such fears/scepticism not only in app design and support, but also to consider what other strategies may be needed to address these concerns.

3.3. Theme 3: diverse design concerns

Through our collection of diverse narratives, design concerns emerged. The technical issues that concerned or were raised by the advisors, farming organisations and government staff, included: (i) smartphone camera size - there were concerns regarding its ability to capture the full extent of the issue under query via the app; (ii) GDPR issues - questions whether supporting agents will be in a position to submit a geotag image via the app on behalf of farmers, from his/her own device were raised and (iii) offline options - concerns were expressed about those living with poor internet reception. Questions such as (i) how will payment delays be prevented? (ii) how will user-authentication work? (iii) how will users be assured that their geotag image has been successfully submitted/under review? (iv) how will users be supported if they encounter problems whilst using the app? and (v) how will farmers be prevented from fixing the problem queried before submitting a photo? were asked during the design thinking process.

"Make sure that they know that once they upload a photo that they get a simple confirmation message saying 'yeah, that has gone through' wherever it's supposed to go to in the department of agriculture" (Farming Organisation, one-to-one interviews).

3.3.1. Process reflection

When developing new innovations, designers have many challenges

to ensure that product design outcomes are relevant and appropriate for users whose needs, expectations, and desires can be very dynamic (McDonagh and Thomas, 2012). Design thinking however, offers a framework for orienting diverse project teams around problems, as they exist within, and are experienced by end-users, rather than relying on their own design assumptions and biases (Roberts et al., 2016). Furthermore, it allows for tacit and experiential knowledge to be utilised in the design process. In our study, we developed a deep and diverse understanding of the explicit and latent needs, desires and values of our user group by engaging in a productive dialogue with end-users and other stakeholders regarding their perceived design preferences and concerns. Results revealed that a number of persistent constraints to smartphone use exist for farmers, in that many feel they lack the capacity and confidence to navigate a smartphone, or they lack access to engage with a smartphone. Gaining this insight at such an early stage in the design thinking process allowed the design and development team to easily implement changes or features that had been recommended, in subsequent stages of the process. For example, as a result of the feedback obtained in the interviews and focus groups, the addition of a feature allowing for offline photo capture was prioritised for the second engineering release (prototype 2) and prior to large scale testing.

The following figure demonstrates how an idea generated by a workshop participant can be transformed into a designed feature.

The design thinking approach (Fig. 3) shows that by allowing farmers and other stakeholders to communicate their needs in an open and communicative space can improve the design teams' awareness and understanding of farmers' local contexts and supports required, and discover ways to meet these needs in subsequent design phases.

3.4. Theme 4: Co-creating solutions

Early stakeholder engagement through co-design allows for a much broader scope of what is needed within a new product or application. A number of solutions were developed by multiple actors in the design thinking process, and specifically in the user workshops in response to the issues and concerns voiced during the earlier stages of the design thinking process. Some of these are outlined in Table 3 below:

3.4.1. Process reflection

Solution development involves creating alternative ways by which the problem can be addressed. Similar to RRI, a dynamic, iterative process was used to develop design-oriented solutions to many of the concerns raised in the early stages of our design thinking approach. Design thinking facilitated an inclusive approach in which various actors worked together during the *ideation* phase and became mutually responsive to each other to co-create the getotag photo app. This collaboration was vital so that respective stakeholders in the innovation process could share responsibility for both the app design process and its outcome and create value for end-users.

Specifically, we observed how creativity was unleashed during the *ideation* phase. Creativity-focused exercises employed in the workshops, such as the user personas, were particularly helpful as they allowed participants to think beyond their personal experiences and consider different scenarios relating to the app. Furthermore, the use of the crazy 8's activity not only stimulated discussion among participants on an array of 'How might we…?' questions, but also led to instances of knowledge co-creation at the intersection of lived experience, farming expertise, and technical solutions. This enabled us to leverage the synergy of the stakeholders to reach refined solutions to the challenges raised in the focus groups and interviews. For example, the provision of real-time support as well as issues with the accessibility to timely responses in times of need were considered critical for subsequent use. This stakeholder input equipped our designers with knowledge that farmers and other stakeholders desire an app that will ultimately enhance information flow, mutual understanding, responsiveness, and accountability between them and their governing body. Furthermore, during the co-design workshops multiple stakeholders stated that prospective end-users would require an intuitive, easy-to-use monitoring tool with clear and concise data visualization, within the app. This dialogue allowed us to capture a clear course of future action; that is, to work on developing an app that meets the information needs and technological abilities of all end-users so that it is acceptable to and feasible for them; an outcome that may not have been possible without an iterative process such as design thinking, that allows for reflexivity and responsiveness to all stakeholders needs and concerns.

By involving future users as co-designers, users were not just viewed as sources of information, rather they were active participants in the design process. The co-design workshops allowed them to actively collaborate with designers on the app design process and contribute knowledge and perspectives that would not perhaps be reached otherwise. Furthermore, for the design and development team, this approach gave a clear understanding of the user's expectations; and vice versa, the end-users of the app know what to expect from the app, which we hope in turn will lead to an improved adoption rate.

4. Discussion

4.1. Design thinking as a methodological framework to implement RRI

In the literature, there is a growing recognition through RRI that research and innovation needs to move beyond preoccupation with technological advancement and economic benefits of individual technologies, to address the innovation process more fully, including social as well as technical aspects (Blok and Lemmens, 2015; Von Schomberg and Blok, 2019). According to Bronson (2019) norms and values are not something that can be taken out of the production of technologies, rather, they ought to be made explicit and deliberated upon as a way of matching them to societal values, preferences and choice. Failing to acknowledge implicit values can create unexpected negative social and ethical implications when technology is broadly adopted, such as marginalising some groups, or further benefiting those who are already privileged (Van der Burg et al., 2019; Klerkx & Begemann, 2020; Klerkx & Rose, 2020). As such, it is no longer enough to reflect on whether new technology is merely viable, but also whether it is fit for the diversity of futures into which it may be deployed, and moreover, ask social and ethical questions about whether its impact will be positive or negative, and for whom (Fleming et al., 2021). In light of this, gaining an understanding of how potential users ask questions, articulate issues, and define problems represent an important element of the innovation process when it comes to developing new forms of digital communication. RRI is particularly valuable for digital agriculture in addressing the social element of innovation, as it recognises the need for purposeful and understanding-oriented communication with a variety of social actors (Ingram & Gaskell, 2019). RRI fosters the importance of stakeholder inclusion, anticipates stakeholder needs, reflects on their feedback, and supports decisions relating to new solutions offered to society. While research and development organisations globally, both public and private, are heavily investing in developing digital agriculture technologies for a successful future, to achieve an equitably realised digital farming tool, a high level of social innovation among corporations, public sector scientists and engineers, government funding agencies, professional associations, activists and academics is required (Bronson, 2019). In agriculture, the importance of involving stakeholders in the development of digital technologies is well understood, and many examples of participatory user-consultation in the literature exist, however, Ingram & Gaskell (2019) have pointed out that this is often through soliciting user-feedback about tool performance and ease of use (Ingram et al., 2016; Rose and Chilvers, 2018) rather than engaging users in the core design processes. This paper, however, demonstrates that design thinking can be used to embed RRI principles in research projects which aim to develop digital technologies for the farming sector. Design thinking required us to think differently and ask different types of

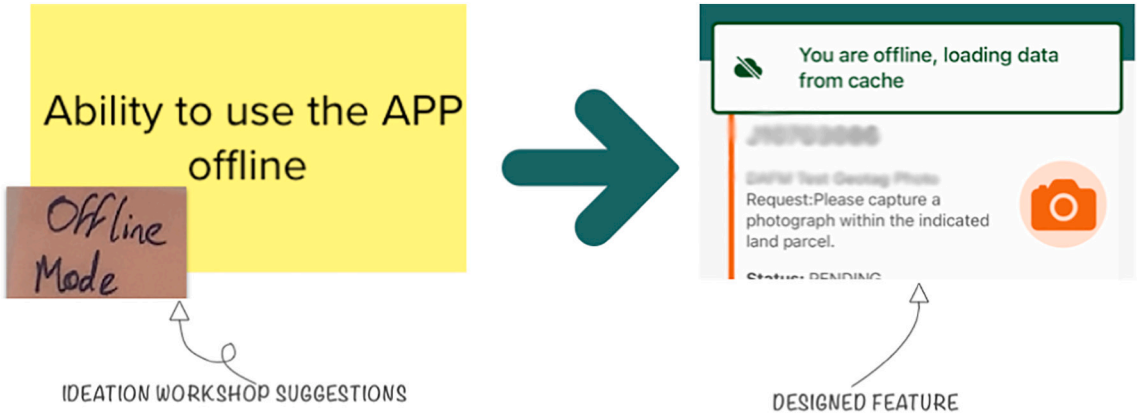


Fig. 3. An idea generated by a workshop participant transformed into a designed feature.

questions during the course of the research process and encouraged consideration of RRI dimensions of anticipation and reflexivity, inclusivity and responsiveness among the research team.

The co-design workshops opened a reflective space where farmers could articulate and share values on the past and future claims process. Relating to the future is both crucial and a key challenge for participatory activities to stimulate responsible innovation – whether the focus is on generating ideas or, as in our case, on constructing values to guide innovation. The attempt to relate to the future can be framed as anticipation (Nordmann, 2019); a key component of RRI. Stimulating stakeholder reflections about whether the app could bring about desirable future farming practices, viewed from within present, practical, and personal contexts helped us in addressing the innovation process more fully, that is to consider social, ethical and technical aspects. This exercise was particularly useful as it served to guide, prompt and open up space for essential governance discussions aimed at supporting, but not dictating, decisions about the framing, direction, pace and trajectory of the app development process. At the same time, in the current study, it was evident that tensions can arise when attempting to simultaneously design user-friendly solutions (an ultimate aim of design thinking) and consider more broadly diverse values and goals as to where and how use of technology is envisioned in the future of farming (an ultimate aim of RRI). Given that design thinking ultimately encourages solutions-oriented thinking, this can in some respects, present a tension to the more overarching aims of RRI. For example, the methodologies of design thinking are geared towards supporting an end-user to embrace acceptable change in the immediate future (e.g. with the development of a specific technology) whereas RRI considers the longer-term impacts, positive, negative or unintended, which could arise from that change. In prioritising the 'now' of technology design, design thinking methodology can be limited in the extent to which it can fully address this latter aim for RRI. This is a tension which should be noted for scholars to attend to in future studies wishing to utilise these methodologies and frameworks. An additional point in this section relates to our learning process and reflexivity, as a research team. While moving along the co-design process, we were continuously confronted with our own scientifically grounded assumptions about farming practices and technology development. When initially conceptualising the app prototype, for example, we placed much greater emphasis on the technological design components of the app (e.g. ability to adequately capture a geotagged photo), neglecting the importance of communication aspects, which turned out to be an essential component for our users. Being open to this learning process, despite being challenging at times, was indispensable and allowed us to collaborate with our stakeholders on a more needs-based level. We thus argue that being conscious and reflective about the underpinnings of our work, a key tenet of RRI, helps us, as research teams, to maintain our research integrity and minimise the risk of tokenism when co-designing (agricultural) solutions with different stakeholders. Without such critical reflection, we believe that research teams may fail to explore alternative solutions and instead fixate on pre-set notions and ideas, which may result in suboptimal design and development choices. As such, we would encourage other research teams aiming to co-design new digital technologies to actively reflect upon and prioritise multiple stakeholders' lived experience instead of relying on existing theoretical models alone to inform the design and development of new technologies.

4.2. *Use of design thinking methodology in digital agriculture*

Until relatively recently, the generation of new agricultural innovations has largely been based on a linear model; research organisations have produced the scientific and technical knowledge needed, with little to no input from innovation end-users, such as farmers and other members of the agricultural community. This model has led to the rapid development of stimulating innovations which have greatly increased agricultural yields, however, it has been shown to fail at educating and engaging farmers on ecological issues (De Snoo et al., 2013) and fails to actively draw on values of progress and innovation that are inherent to farmers (Burton and Paragahawewa, 2011) or other actors in society (Elzen and Bos, 2016). In light of these shortcomings, there have been calls to renew agriculture's traditional organisation of design and technology development (Vanloqueren and Baret, 2009; Meynard et al., 2017) and foster more open, collaborative and participatory approaches to agricultural design and innovation (Berthet et al., 2018). In response such calls, we are now beginning to see an increase in the use of co-design and co-innovation approaches in agricultural research (Fleming et al., 2021; Aare et al., 2021; Romera et al., 2020; Romera et al., 2018), which builds on the well-established use of Participatory Action Research (PAR) in designing agricultural systems (McCown et al., 2002; Carberry et al., 2002). However, relatively less is known about the use of design thinking as a specific methodology for developing a digital technology in agriculture, thus, this paper brings new insights to previous debates (McCown et al., 2002; Carberry et al., 2002) on the inclusion of end-users in the agri-design process. Design thinking, as an approach, aims to blur the boundaries between designers and end-users through its use of iterative interaction, across five key phases of the design process. This approach therefore facilitates continuous knowledge flows between various actors and how to better involve a diversity of actors in design and innovation processes within the agricultural system. However, in the context of designing more sustainable agricultural and agri-food systems, and in view of paradigms such as, smart or digital farming (Pigford et al., 2018), there is a need to consider how design thinking in agriculture can be used to better support both democratic and radical innovation, including concepts, behaviours and technologies (Gardien et al., 2014) among farmers and with other actors with diverging interests and complex power relationships (Barnaud and

Van Paassen, 2013; Berthet et al., 2016). This paper is one of the first to provide an insight into the use of design thinking in an agricultural arena, and in doing so, hopes that it will encourage others to adopt such an approach so that we can work towards a removal of, or at least weaken, the boundaries that, at times exist, between scientists and agricultural system stakeholders and between actors in the agricultural sector and those designing in other sectors.

In an ideal world, a design thinking approach would start from a 'blank slate' and innovations would be freely developed with no strictures or boundaries in place as to the form and function that an innovation would take. In the current study, the design thinking process was beginning with a certain number of parameters already in place; namely, that a technological solution had been pre-identified with the design and deployment of that solution to be shaped using the design thinking process. Pre-existing informal stakeholder engagement processes served to shape the problem definition and selection of the technological solution, however, this engagement took place outside of the formal design thinking methodology put in place for the current project. This is a limitation of the current methodological approach, but it also reflects a practical reality of embedding a design thinking approach within publicly-funded, inter-disciplinary research projects. 'Research impact' has become a centralising feature of research policy and publicly-funded research programmes place a strong emphasis on solutions-oriented research and innovation (Stilgoe et al., 2013). Accordingly, funders assess and award proposals based on their ability to demonstrate tangible returns from research (Gibbons, 1999; Bornmann, 2013; Dinsmore et al., 2014). It is common for research impact frameworks to be put in place by research funding bodies which assess the extent to which research is technology-ready; policy-ready; and/or socially-ready, and to award funding accordingly (Harland and O'Connor, 2015; Department of Agriculture Food and the Marine (DAFM), 2021). In this respect, proposals, particularly those which are shaped by inter-disciplinary thinking, often have to work within certain parameters and the opportunity to start with a blank canvas in innovation design can be limited. Social science, for example with the use of design thinking approaches, can support projects to achieve both RRI and research impact, however, there do remain on-going tensions as to how social science is perceived and can operate within interdisciplinary research settings. Many reasons exist as to why such tensions arise, including the practice of involving few social scientists in interdisciplinary projects late in the research process; a lack of clear frameworks for integrating social and natural sciences (Christie et al., 2003; Campbell, 2005); expectations by natural scientists about the results of social science research; a tendency by natural scientists to see social scientists primarily as educators (as opposed to scholarly researchers); the social context in which natural science has developed (with humans seen as separate from nature); the power dynamics in interdisciplinary teams; and a lack of shared understanding about what is meant by including humans in a research process (Campbell, 2005; MacMynowski, 2007). Overcoming such tensions is no easy task, however efforts should be made to formulate and coordinate research questions and methodologies by interdisciplinary research teams, at the outset of a project. This may require meetings that specifically address epistemological differences so that productive exchanges can occur. Furthermore, projects will require new tools and platforms that reflexively stimulate the curiosity, creativity and problem-solving capacity of all the participating disciplines, which, in turn, will allow for a more substantial role for social scientists.

4.3. Future directions

Based on the key problems and needs identified from the early stages of design thinking, presented in this paper, we aim to commence developing various forms of prototypes. Design thinking methodology will continue to be used to iteratively refine the geotagged photo app and include diverse stakeholder input at every step of the way. We will begin by creating a first prototype and collect users' experiences and feedback. Using this feedback, our team will subsequently refine the app. Following this, large-scale user testing will occur with the final prototype. It will be piloted with both farmers and farm advisors. Qualitative feedback will also be collected from pilot participants which will measure their experience of app use and whether they have any further suggestions before the official roll out of the app is made to the wider farming community.

5. Conclusion

Overall, the goal of this study was to present how a design thinking process can be used for developing a smartphone app in an agricultural domain. The key contribution of this study is that each of the first three stages of design thinking has the potential to support designers and researchers who aim to develop a smartphone app that meets the needs of potential target users and wishes to embed in a tangible way some of the principles captured under RRI. In our study, we engaged the prospective users of the app both in the identification of needs and in the identification of technical solutions that could help to address them. In doing so, we were able to access a previously untapped source of ideas and knowledge, resulting in a rich catalog of desirable features and functionalities of the app prototype. Obtaining these crucial views at the beginning of the design thinking process demonstrates that our project team is responding to the need of improving multi-stakeholder communication in digital agriculture and working towards advancing technological development by obtaining and including end-users' values and preferences early in the design process of new forms of digital communication.

In our study, there was a clear alignment with principles of RRI in that we focused on addressing the socio-ecological needs and challenges of our users; we committed to actively engaging a range of stakeholders for the purpose of substantively improving decision-making and mutual learning; we made a dedicated attempt to anticipate potential problems; and there was a clear willingness among all the development team to act and adapt according to these ideas. We hope that the design process presented in this article provides a guide to harnessing design thinking to create more robust, sustainable agricultural tools in future studies. It is important to note some study limitations. We cannot be sure how truly participatory our co-design approach was. Although we aimed to involve the different stakeholder groups as equal partners, we cannot know with certainty whether this is how they experienced the co-design process, as this was not assessed in the current study. We thus recommend researchers using co-design methodologies to incorporate process evaluations into their research to gain a better understanding of how different stakeholders experience their participation in a design thinking process. Given the focus on diversity, inclusion and reflexivity in the current study, it is important to note the issue of gender bias which emerged during this study. Although efforts were made to ensure gender diversity during sampling, the majority of participants in the design thinking process were male. It was noteworthy that some of our findings highlighted how end-users continue to perceive that spouses (expressed predominantly as farmers' wives) will likely become responsible for submitting the geotagging imagery on their partner's behalf. This finding reflects that a gendered distinction between the productive (male) and reproductive (female) work roles on the farm persist; what scholars note as a dichotomy of identities and roles in the farm household (Shortall and Byrne, 2016; Brandth, 2002). We thus argue that gender relations in agriculture is still an on-going issue and more work is required to acknowledge women's many skills and talents to the farm business which are integral to farm operations, rather than downplaying or devaluing the work they do carry out as 'non-farming' work or 'invisible' work.

To conclude, our research demonstrates that the inclusion of multiple stakeholders in a design thinking process aiming to develop a smartphone app highlighted disparate needs, motivations, and intentions for the app, and by incorporating the views of all, the app has

promise as a tool to assist farmers and their advisors in the management of farming activity going forward. The current study supports the feasibility and desirability of shaping or steering science and innovation using a design thinking approach.[1,2,3,4,5]

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

The European NIVA project is funded by the European Union H2020 Programme. The Irish use case of NIVA is a collaboration between Teagasc (Ursula Kenny and Aine Regan), the Department of Agriculture, Food and the Marine (Eoin Dooley, Anthony Ryan and Tom Forristal), and the Telecommunications Software and Systems Group at Waterford Institute of Technology (TSSG WIT) (Dave Hearne and Christine O'Meara). This research has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 842009. The funding source had no involvement in the study design; in the collection, analysis and interpretation of data; in the writing of the report; and in the decision to submit the article for publication.

Funding information

This research has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 842009. The funding source had no involvement in the study design; in the collection, analysis and interpretation of data; in the writing of the report; and in the decision to submit the article for publication.

Appendix A

Informant Interview Questions

1. What are your initial thoughts on the approach I have just outlined to you?
2. What contribution do you think this technology will make to farming?
3. What impact do you think this technology might have for your role?
4. How do you think farmers will respond to this technology?
5. Explain to me what barriers, if any, will arise for users at the point of adoption?
6. What are your thoughts on the supports that might be needed to facilitate adoption?
7. How do you think farmers can be motivated to adopt this technology?
8. In the final part of the interview now, please take a look at this map we have developed. This map identifies all the main categories of people who will be interested in this technology. Do you think there is category of stakeholder anyone missing from this map? And why might they be important?

Appendix B

Insight Statements and "How Might We…" Questions developed from the Farmer Focus Groups.

Focus group theme	Insight statement	*"How Might We…" Question*
Farmers' General Attitudes towards Smartphones and Apps	Older farmers are not as interested in using smartphones for work as younger farmers are Older farmers are not as willing as younger farmers to use smartphones for work purposes Increased diffusion of smartphones for farming purposes will lead to an exclusion of farmers (who are not tech-savvy)	• *How might we promote interest among older farmers to use smartphones for work?* • *How might we ensure that no farmer is excluded when the new app is introduced?*
Value Propositions	Farmers feel that smartphone apps enable them to live a better quality of life, and run a more profitable and efficient farm Smartphone use whilst working on the farm can be dangerous and distracting Social networking sites are useful platforms to ask queries of / seek support from other farmers	• *How might we show farmers that smartphones are useful for work?* • *How might we demonstrate to farmers that smartphones can be used safely at work?*
Self-Efficacy	Older and middle aged farmers lack self-confidence in their ability to use a smartphone for work Farmers from certain farming sectors are more capable of using a smartphone (for work) Farmers do not trust technology to perform work-related tasks that can be done manually Farmers who have had negative experiences with technology are not interested in pursuing them further	• *How might we help farmers to become more confident in their ability to use a smartphone?* • *How might we help farmers from all farming sectors to become equally as progressive on smartphone use?* • *How might we promote trust in technology use among farmers?* • *How might we help farmers to overcome past negative experiences with technology?*

(*continued on next page*)

[1] https://www.niva4cap.eu/
[2] https://www.designkit.org/methods/3
[3] Due to restrictions introduced in March 2020 as a result of the COVID-19 Pandemic, it was not possible to host any further face-to-face workshops.
[4] https://www.mural.co/
[5] https://www.zoom.us/

(*continued*)

Focus group theme	Insight statement	*"How Might We…" Question*
Accessibility	Farmers living in areas of poor internet connection will not use farm-related apps	• *How might we overcome internet connection issues for farmers so that they can use the app?*
	Farmers often have to rely on local establishments (e.g. pubs) for internet connection	• *How might we support farmers so that expense of a smartphone is not a barrier to use?*
	Farmers find traditional phones more appealing than smartphones as they are less expensive and less likely to break or to be stolen	
Socio-cultural Beliefs	Communication between farmers and the Department is seen as inefficient	• *How might we improve communication between farmers and the Department?*
	Farmers lack control over the communication process with the Department	• *How might we enhance farmers' level of control over the communication process with the Department?*
	Departmental monitoring of farmers and their farming activity will increase as a result of the app	
	Farmers may indirectly self-implicate when submitting geotagged photos via the app	• *How might we tackle the worry of increased monitoring of farms as a result of using this app?*
		• *How might we tackle the concern of farmers self-implicating themselves when submitting geotagged photos* via *the app?*
Keys to success	Farmers need to be trained on how to use the app	• *How might we train farmers on using the app?*
	Training must be simple and delivered in a targeted manner (e.g. low vs. high IT skills)	• *How might we best deliver training sessions to farmers on the use of this app?*
	Farm advisors and Departmental staff will require training	• *How might we train Departmental staff and supporting agents?*
	Failure to impress users at the stage of launch will lead to a sense of distrust in the app	• *How might we successfully launch the app?*
	The app will fail if it is poorly designed, complex to use and if technical errors arise	• *How might we successfully design the app for farmers so that it is easy to use and no errors arise?*
Digital divide	Farmers who do not use smartphones will not be capable of using the app	• *How might we help farmers who do not currently use smartphones to adopt the app?*
	Farmers who use smartphones for basic purposes (making calls) only, will struggle with the app	• *How might we understand what level of help farmers will need from other people to use this app?*
	Farmers will rely on others to submit the requested geotagged image to the Department	• *How might we help farmers, who have nobody they can call on, to acquire the skills they need to use the app?*
	Not all farmers have someone to rely on to conduct the geotagging photo task for them	• *How might we ensure that farmers who will not be able to use the app will not feel isolated and left behind?*
	There is a risk that farmers who will not be able to use the app will feel isolated and left behind	

Insight statements developed from the Key Informant Interviews.

Interview Theme	Insight Statement	*"How Might We…" Question*
Current experience with geotagging technology	Not all advisors find the geotagging photo task straight forward	• *How might we make the photo geotagging task more straightforward to use for advisors?*
	Not all advisors feel that the geotagging system makes their work easier	• *How might we ensure that the geotagging app will make life easier for advisors?*
Workload	Farmers will rely on advisors to submit geotagged photos on their behalf, therefore, their current workload will increase	• *How might we ensure that advisors are not overwhelmed by farmers who need help with the app?*
	The app is being developed for the benefit and convenience of the Department, not the farmer or advisor	
	The app will reduce work for the Department, not for the farmer or supporting agents	• *How might we ensure that farmers and supporting agents believe that the app is being developed for the benefit of farmers?*
		• *How might we ensure that farmers and farm advisors believe that the app will reduce their workload?*
Protecting & enabling farmers	The app should not fully replace on the ground inspections	• *How might we ensure that the app does not replace on-the-ground inspections where they are needed?*
	Farmers might self-implicate, when submitting geotagged photos to the Department on the app	• *How might we tackle the concern of farmers self-implicating themselves when submitting geotagged photos* via *the app?*
Farmers' Rights	All rights currently granted to farmers should be maintained once the app is rolled out	• *How might we ensure that all of the current rights of the farmer are maintained once the app is introduced?*
	Farmers should not incur a penalty if they choose not to submit a geotagged photo via the app	• *How might we ensure that farmers know that they will not incur a penalty if they choose not to use the app?*
	The implications for farmers who send in too many photos, the incorrect photo, and/or bad quality photo is unclear	• *How might we communicate to farmers and advisors, what implications, if any, exist for farmers and supporting agents who submit incorrect information* via *the app?*
	Farmers' rights to data protection whilst using the app or relying on someone else to use the app on their behalf are not clear	
	A farmers consent must be sought before an inspector is permitted to photograph their land, as part of an appeal/inspection process	

(*continued on next page*)

(*continued*)

Interview Theme	Insight Statement	*"How Might We…" Question*
		• *How might we protect farmers' rights to data protection when they are using the app?*
		• *How might we protect farmers' rights to data protection, if they are relying on someone else to use the app on their behalf?*
Technical Considerations	Farmers with a lack of access to a computer, smartphone or Wi-Fi will resist the new technology	• *How might we overcome a farmers' lack of access to internet connectivity, should they wish to use the app?*
	There is a risk that farmers, who are not tech-savvy, will be left behind	
	Not all phones will be app-compatible	
	It will be difficult to submit evidence of the issue under query to the Department, via the app, using a small smartphone camera	• *How might we overcome the issue of certain phones not being compatible to app use?*
	Supporting agents feel that farmers need to be given a guaranteed time line of when an application will be cleared for payment, if they choose to use the app	• *How might we ensure that the smartphone camera adequately captures the issue under query?*
		• *How might we provide assurance to farmers that their application will be processed on time?*
App Features	The app must include a multiple user function so that supporting agents can help farmers to submit their geotagged images to the Department	• *How might we create a multi-user app?*
	The app has to be very simple, straight forward and easy to use for farmers	• *How might we design an app that farmers agree is easy to use?*
	An authentication process that will confirm a farmers' identity needs to be incorporated into the app	
	An authentication process that allows for supporting agents to submit geotagged photos on behalf of farmers is needed	• *How might we design an app that will confirm a users' identity?*
	Farmers will not be able to use the technology without an in-app support system	• *How might we design an in-app support service?*
	Individual supporting agents need to be registered with the Department, as users of the app, given GDPR issues around 3rd party data	• *How might we overcome GDPR issues, if farmers are relying on others to use the app on their behalf?*
Age	Older farmers are not technologically advanced and will struggle with the app	• *How might we ensure that all farmers, regardless of their age, will be able to understand what the app is for and make informed decisions about using it?*
	Older farmers will not understand what is required of them with the new app	
	The app will give rise to age discrimination issues	
	Older farmers who cannot use the app will have to bare an extra cost of paying advisors to perform the geotagging photo task for them	• *How might we ensure that age discrimination will not be an issue?*
	Older farmers will not reap the benefits of reduced farm inspections because they will not be capable of using the app	• *How might we help farmers who cannot use technology to overcome the cost of paying an advisor to do the task for them?*
		• *How might we ensure that farmers, who cannot use the app, will receive equal benefits of reduced inspections?*
Fears	Adoption of the app will be slow, due to fears and mistrust, and will depend on how the app is pitched to farmers	• *How might we overcome a slow initial adoption of the app due to fears and mistrust?*
	Farmers will be nervous that the app will enable the Department to monitor everything they are doing	
	Supporting agents are concerned about farmers' rights to data protection	• *How might we pitch the app to end-users?*
	There is no guarantee that the Department will deal with each submitted geotagged photo in an efficient manner	
	Inspectors feel that the current process of dealing with overclaims is better than the proposed move to an app-based process, because the inspector has more control	• *How might we overcome concerns that the app will allow the Department monitor everything the farmer is doing?*
		• *How might we ensure that the app is as efficient as promised?*
		• *How might we overcome inspectors' fears that they will lose control if the app is introduced?*
Trust	Inspectors do not trust farmers or advisors to take honest photos of the issue under query	• *How might we encourage and build trust between inspectors and farmers / farm advisors when it comes to submitting photos?*
	Inspectors' jobs will be undermined because farmers will rectify the issue before an inspector comes out for a field visit	
	An in-time process is needed so that farmers cannot correct the issue under query before submitting their photo	• *How might we ensure that an inspector's job is not undermined?*
	The app will not facilitate an open-ended arrangement between the Department and the farmer	• *How might we capture an in-time process with the app?*
	There has to be implications in place for farmers who ignore requests to submit geotagged photographic evidence to the Department via the app	• *How might we treat farmers who ignore a departmental request to submit a photo* via *the app?*
Motivational factors (app use)	A simplistic app design will motivate farmers to use the technology	• *How might we create big writing on the app?*
	Large writing and buttons will enable farmers to use the app	

(*continued on next page*)

(*continued*)

Interview Theme	Insight Statement	*"How Might We…" Question*
	An app that is operable without internet connectivity will enhance adoption rates	
	A confirmation message that the geotagged image has been successfully submitted to the Department will encourage farmers to use the app	• *How might we create an app that works offline?*
	The Department needs to make a commitment to farmers that appeals will be dealt with in a more efficient manner	• *How might we ensure that a confirmation message is sent to farmers once they have submitted their photo?*
	Adoption will be largely dependent on how intensively and where (media) the app is pitched to farmers	• *How might we advertise the app to farmers?*
Training and support	Farmers, advisors and FOs need to be trained on how to use the app	• *How might we train all end-users of the app?*
	Farmers need supporting agents to be in place to help with app use once it is rolled out	
	Practical sessions to teach farmers how to use app are necessary	• *How might we ensure that supporting agents are trained before the app is rolled out?*
	Training sessions for farmers must delivered in an extremely simplistic manner	
	Farmer's spouses and children will require training on how to use the app	• *How might we deliver practical sessions to farmers?*
		• *How might we ensure that the training is delivered in a simplistic manner?*
		• *How might we train farmers' spouses, children and other dependants?*

Appendix C

User Profile 1

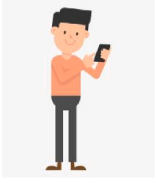
JAMES

Gender: Male

Age: 60

Location: Galway

Role: Dairy Farmer



Barriers:

I do not own and cannot use a smartphone

I would not feel confident using a smartphone app

The introduction of new technologies means that I will be left behind

Facilitators:

If there was an incentive to learn, I would do my best

My advisor will help me to do what is needed or he will do it on my behalf

Goals:

- Stay doing what I know and I am comfortable with
- Draw on my years of farming experience to do my job

User Profile 2

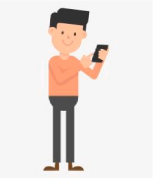
CONOR

Gender: Male

Age: 65

Location: Kerry

Role: Sheep Farmer



Barriers:

I do not trust technology or the Department

I feel smartphones are a dangerous distraction on farms

Facilitators:

If it can guarantee that my payments will be processed quicker, I would consider using it or get someone else to use it for me

Goals:

- Maintain a safe workplace
- Live as simple a life as possible, without any extra stress or hassle

User Profile 3

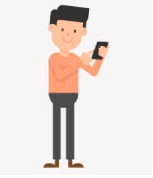
DAVID

Gender: Male

Age: 28

Location: Meath

Role: Beef Farmer



Barriers:

My farm has poor internet connection

If an app is complex to use and contains errors, it would not interest me

Facilitators:

I am tech-friendly and love farming apps

Apps have made my working life easier & have improved my quality of life

The app will take away the fear of inspections

Goals:

- Keep up-to-date on farming technologies
- Maintain a good work-life balance

User Profile 4

KATHLEEN

Gender: Female

Age: 44

Location: Mayo

Role: Pig farmer

Barriers:

I will be monitored more than ever if I use the app

I could risk sending a photo of something that will get me into trouble with the Department

Facilitators:

The app will greatly improve my communication with the Department

The app will reduce the burden of paperwork I face each week

The app gives me control over farm inspections

Goals:

- Maintain the privacy of myself and my farm
- Open to anything that makes my life easier and improves my quality of life

User Profile 5

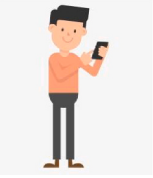
LUKE

Gender: Male

Age: 55

Location: Carlow

Role: Farm Advisor



Barriers:

My workload will increase because farmers will rely on me to do this

I feel that a multiple user log on will be an issue

Farmers, especially older farmers, will be slow to trust this

Facilitators:

I have good tech ability so using an app will not be a problem for me

I believe an app would help deal quickly with overclaim issues

Goals:

- Maintain a good work-life balance
- Provide support to farmers

User Profile 6

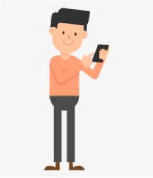
RYAN

Gender: Male

Age: 60

Location: Dublin

Role: Farming Organisation



Barriers:

Farmers' right to request on-the- ground inspections will be minimised

Concerns about data protection

Farmers' could self-implicate themselves with app photos

Facilitators:

The app would reduce farmers' stress about on-farm inspections

The app would improve communication with the Department

Goals:

- Fight to make sure the rights of farmers are protected
- Empower farmers

User Profile 7

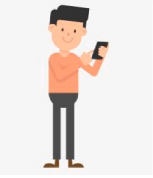
DANIEL

Gender: Male

Age: 48

Location: Laois

Role: Inspector



Barriers:

My job will be undermined

I have concerns about photos being manipulated

Age discrimination may be an issue

Facilitators:

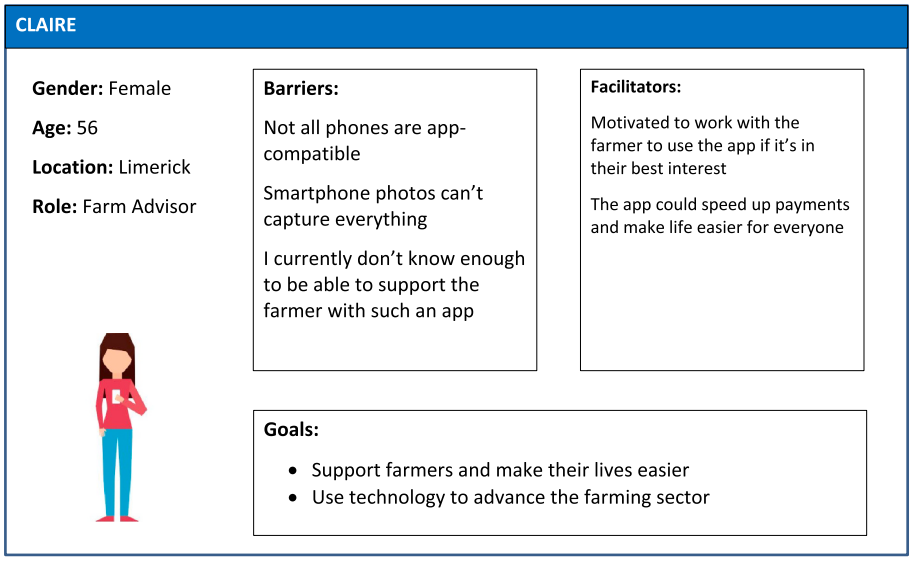
The app will help me to deal with appeals and over-claims more efficiently

I am very experienced with what is required for the geotagging photo system

Goals:

- That my experience and expertise as an inspector is recognised
- Ensure a fair approach is always undertaken

User Profile 8



References

Aare, A.K., Lund, S., Hauggaard-Nielsen, H., 2021. Exploring transitions towards sustainable farming practices through participatory research–the case of Danish farmers' use of species mixtures. Agric. Syst. 189.

Agyekumhene, C., De Vries, J., Paassen, A.V., Schut, M., MacNaghten, P., 2020. Making smallholder value chain partnerships inclusive: exploring digital farm monitoring through farmer friendly smartphone platforms. Sustainability 12 (11), 4580.

Ayre, M., Mc Collum, V., Waters, W., Samson, P., Curro, A., Nettle, R., Reichelt, N., 2019. Supporting and practising digital innovation with advisers in smart farming. NJAS-Wageningen J. Life Sci. 90-91, 100302.

Baeck, A., Gremett, P., 2012. Design Thinking: Expanding UX methods beyond designers. *Degen, H., Yuan, X.: UX Best Practices. How to Achieve More Impact with User Experience. McGrawHill*, pp. 230–250.

Barcellini, F., Prost, L., Cerf, M., 2015. Designers' and users' roles in participatory design: what is actually co-designed by participants? Appl. Ergon. 50, 31–40.

Barnaud, C., Van Paassen, A., 2013. Equity, power games, and legitimacy: dilemmas of participatory natural resource management. Ecol. Soc. 18 (2).

Beaird, G., Geist, M., Lewis, E.J., 2018. Design thinking: opportunities for application in nursing education. Nurse Educ. Today 64, 115–118.

Berthet, E.T., Barnaud, C., Girard, N., Labatut, J., Martin, G., 2016. How to foster agroecological innovations? A comparison of participatory design methods. J. Environ. Plan. Manag. 59 (2), 280–301.

Berthet, E.T., Hickey, G.M., Klerkx, L., 2018. Opening design and innovation processes in agriculture: insights from design and management sciences and future directions. Agric. Syst. 165, 111–115.

Blok, V., Lemmens, P., 2015. The Emerging Concept of Responsible Innovation. In: Three Reasons why it Is Questionable and Calls for a Radical Transformation of the Concept of Innovation. In Responsible Innovation 2 (Pp. 19–35). Springer, Cham.

Bornmann, L., 2013. What is societal impact of research and how can it be assessed? A literature survey. J. Am. Soc. Inf. Sci. Technol. 64, 217–233.

Brandth, B., 2002. Gender identity in European family farming: a literature review. Sociol. Rural. 42 (3), 181–200.

Bronson, K., 2019. Looking through a responsible innovation lens at uneven engagements with digital farming. NJAS-Wageningen J. Life Sci. 90-91, 100294.

Brown, T., 2008. Design thinking. Harv. Bus. Rev. 86 (6), 84.

Burton, R.J., Paragahawewa, U.H., 2011. Creating culturally sustainable Agri-environmental schemes. J. Rural. Stud. 27 (1), 95–104.

Campbell, L.M., 2005. Overcoming obstacles to interdisciplinary research. Conserv. Biol. 19 (2), 574–577.

Carberry, P.S., Hochman, Z., McCown, R.L., Dalgliesh, N.P., Foale, M.A., Poulton, P.L., Robertson, M.J., 2002. The FARMSCAPE approach to decision support: farmers', advisers', researchers' monitoring, simulation, communication and performance evaluation. Agric. Syst. 74 (1), 141–177.

Carolan, M., 2018. Smart'farming techniques as political ontology: access, sovereignty and the performance of neoliberal and not-so-neoliberal worlds. Sociol. Rural. 58 (4), 745–764.

Christie, P., McCay, B.J., Miller, M.L., Lowe, C., White, A.T., Stoffle, R., Lowry, K., 2003. Toward developing a complete understanding: a social science research agenda for marine protected areas. Fisheries 28 (12), 22–26.

Clarke, V., Braun, V., 2014. Thematic analysis. In: *Encyclopedia of critical psychology* (pp. 1947-1952). Springer, New York NY.

Crites, K., Rye, E., 2020. Innovating language curriculum design through design thinking: a case study of a blended learning course at a Colombian university. System 94, 102334.

De Snoo, G.R., Herzon, I., Staats, H., Burton, R.J., Schindler, S., van Dijk, J., Musters, C.J. M., 2013. Toward effective nature conservation on farmland: making farmers matter. Conserv. Lett. 6 (1), 66–72.

Department of Agriculture Food and the Marine (DAFM), 2021. Research Impact Guidance. Available online. https://www.gov.ie/en/publication/3d715-dafm-announces-2021-call-for-research-proposals/. (Accessed 13 May 2021).

Dinsmore, A., Allen, L., Dolby, K., 2014. Alternative perspectives on impact: the potential of ALMs and Altmetrics to inform funders about research impact. PLoS Biol. 12 (11).

Dogliotti, S., García, M.C., Peluffo, S., Dieste, J.P., Pedemonte, A.J., Bacigalupe, G.F., Rossing, W.A.H., 2014. Co-innovation of family farm systems: a systems approach to sustainable agriculture. Agric. Syst. 126, 76–86.

Doorley, S., Holcomb, S., Kliebahn, P., Segovia, K., Utley, J., 2018. Design Thinking Bootleg (Hasso Plattner Institute of Design at Stanford).

Eastwood, C., Klerkx, L., Ayre, M., Rue, B.D., 2019. Managing socio-ethical challenges in the development of smart farming: from a fragmented to a comprehensive approach for responsible research and innovation. Journal of Agricultural and Environmental Ethics 32 (5), 741–768.

Elzen, B., Bos, B., 2019. The RIO approach: design and anchoring of sustainable animal husbandry systems. Technol. Forecast. Soc. Chang. 145, 141–152.

EU SCAR, 2012. Agricultural Knowledge and Innovation Systems in Transition – Reflection Paper. European Commission, Brussels.

EU SCAR, 2014. Agricultural knowledge and innovation systems towards 2020 – an orientation paper on linking innovation and research. European Commission. Brussels. Faure, G., Rebuffel.

Fielke, S., Taylor, B., Jakku, E., 2020. Digitalisation of agricultural knowledge and advice networks: a state-of-the-art review. Agric. Syst. 180, 102763.

Fleming, A., Mason, C., Paxton, G., 2018. Discourses of technology, ageing and participation. Palgrave Communications 4 (1), 1–9.

Fleming, A., Jakku, E., Fielke, S., Taylor, B.M., Lacey, J., Terhorst, A., Stitzlein, C., 2021. Foresighting Australian digital agricultural futures: applying responsible innovation thinking to anticipate research and development impact under different scenarios. Agric. Syst. 190.

Fossum, S.M., Barkved, L.J., Throne-Holst, H., 2019. Practicing Responsible Research and Innovation in a Crowdsourcing Project.

Gardien, P., Djajadiningrat, T., Hummels, C., Brombacher, A., 2014. Changing your hammer: the implications of paradigmatic innovation for design practice. Int. J. Des. 8 (2).

Genus, A., Stirling, A., 2018. Collingridge and the dilemma of control: towards responsible and accountable innovation. Res. Policy 47 (1), 61–69.

Gibbons, M., 1999. Science's new social contract with society. Nature 402, C81–C84.

Guston, D.H., 2014. Giving Content to Responsible Innovation.

Harland, K., O'Connor, H., 2015. Broadening the scope of impact. Defining, assessing and measuring impact of major public research programmes, with lessons from 6 small advanced economies. SAEI march, v.2.

Hendricks, S., Conrad, N., Douglas, T.S., Mutsvangwa, T., 2018, September. A modified stakeholder participation assessment framework for design thinking in health innovation. In: *Healthcare* (Vol. 6, No. 3, pp. 191-196). Elsevier.

Henriksen, D., Richardson, C., Mehta, R., 2017. Design thinking: a creative approach to educational problems of practice. Think. Skills Creat. 26, 140–153.

Inigo, E.A., Blok, V., 2019. Strengthening the socio-ethical foundations of the circular economy: lessons from responsible research and innovation. J. Clean. Prod. 233, 280–291.
Ingram, J., Gaskell, P., 2019. Searching for meaning: Co-constructing ontologies with stakeholders for smarter search engines in agriculture. NJAS-Wageningen Journal of Life Sciences 90, 100300.
Jakku, E., Thorburn, P.J., 2010. A conceptual framework for guiding the participatory development of agricultural decision support systems. Agric. Syst. 103, 675–682.
Jakku, E., Taylor, B., Fleming, A., Mason, C., Fielke, S., Sounness, C., Thorburn, P., 2019. "If they don't tell us what they do with it, why would we trust them?" trust, transparency and benefit-sharing in smart farming. NJAS-Wageningen J. Life Sci. 90, 100285.
Kelley, D., 2001. The Art of Innovation: Lessons in Creativity from IDEO, America's Leading Design Firm. Doubleday, New York.
Khalid, H.M., 2006. Embracing diversity in user needs for affective design. Appl. Ergon. 37 (4), 409–418.
Klerkx, L., Van Mierlo, B., Leeuwis, C., 2012. Evolution of Systems Approaches to Agricultural Innovation: Concepts, Analysis and Interventions. In: In Farming Systems Research into the 21st Century: The New Dynamic (Pp. 457–483). Springer, Dordrecht.
Klerkx, L., Jakku, E., Labarthe, P., 2019. A review of social science on digital agriculture, smart farming and agriculture 4.0: new contributions and a future research agenda. *NJAS-Wageningen journal of*. Life Sci. 90-91, 100315.
Krueger, R.A., Casey, M.A., 2014. Designing and Conducting Focus Group Interviews. Social Analysis Selected Tools and Techniques, The World Bank.
Klerkx, L., Begemann, S., 2020. Supporting food systems transformation: The what, why, who, where and how of mission-oriented agricultural innovation systems. Agricultural systems 184, 102901.
Klerkx, L., & Rose, D., (2020), Dealing with the game-changing technologies of Agriculture 4.0: How do we manage diversity and responsibility in food system transition pathways?, Global Food Security, 24, 100347.
Lazzaro, M., Paree, P., Guidotti, D., Koltsida, P., Benians, S., Barberi, P., Toli, E., 2018. Digital tools co-creation to ease the dialog among farmers' communities with diverse visions. A practical case with conventional and organic farmers in CAPSELLA' (In Proceedings of the European IFSA Symposia 2018).
Lin, L., Shadiev, R., Hwang, W.Y., Shen, S., 2020. From knowledge and skills to digital works: an application of design thinking in the information technology course. Think. Skills Creat. 36, 100646.
MacMynowski, D.P., 2007. Pausing at the brink of interdisciplinarity: power and knowledge at the meeting of social and biophysical science. Ecol. Soc. 12 (1).
Macnaghten, P., Owen, R., Stilgoe, J., Wynne, B., Azevedo, A., de Campos, A., Garvey, B., 2014. Responsible innovation across borders: tensions, paradoxes and possibilities. J. Respon, Innov. 1 (2), 191–199.
McCown, R.L., Hochman, Z., Carberry, P.S., 2002. Probing the Enigma of the Decision Support System for Farmers: Learning from Experience and from Theory.
McDonagh, D., Thomas, J., 2012. Rethinking design thinking: empathy supporting innovation. Austr. Med. J. 3 (8), 458–464.
Meynard, J.M., Jeuffroy, M.H., Le Bail, M., Lefèvre, A., Magrini, M.B., Michon, C., 2017. Designing coupled innovations for the sustainability transition of agrifood systems. Agric. Syst. 157, 330–339.
Nordmann, A., 2019. The Ties that Bind: Collective Experimentation and Participatory Design as Paradigms for Responsible Innovation. Edward Elgar Publishing, In International Handbook on Responsible Innovation.
Pigford, A.A.E., Hickey, G.M., Klerkx, L., 2018. Beyond agricultural innovation systems? Exploring an agricultural innovation ecosystems approach for niche design and development in sustainability transitions. Agric. Syst. 164, 116–121.
Reed, M.S., 2008. Stakeholder participation for environmental management: a literature review. Biol. Conserv. 141 (10), 2417–2431.
Regan, Á., 2019. 'Smart farming' in Ireland: a risk perception study with key governance actors. NJAS-Wageningen J. Life Sci. 90-91, 100292.
Roberts, J.P., Fisher, T.R., Trowbridge, M.J., Bent, C., 2016, March. A design thinking framework for healthcare management and innovation. In: *Healthcare* (Vol. 4, No. 1, pp. 11-14).
Romera, A.J., Neal, M., & Bos, A.P., 2018, Re-designing New Zealand dairy systems: public preferences. In 41° Congreso de la Asociacion Argentina de Producción Animal–Revista Argentina de Producción Animal (pp. 16-19).
Romera, A.J., Bos, A.P., Neal, M., Eastwood, C.R., Chapman, D., McWilliam, W., Clinton, P.W., 2020. Designing future dairy systems for New Zealand using reflexive interactive design. Agric. Syst. 181.
Rose, D.C., Chilvers, J., 2018. Agriculture 4.0: broadening responsible innovation in an era of smart farming. Front. Sustain. Food Sys. 2, 87.
Rose, D.C., Sutherland, W.J., Parker, C., Lobley, M., Winter, M., Morris, C., Twining, S., Ffoulkes, C., Amano, T., Dicks, L.V., 2016. Decision support tools for agriculture: towards effective design and delivery. Agric. Syst. 149, 165–174.
Rose, D.C., Wheeler, R., Winter, M., Lobley, M., Chivers, C.A., 2020. Agriculture 4.0: making it work for people, production, and the planet. Land Use Policy 100, 104933.
Schot, J., Steinmueller, W.E., 2016a. Framing innovation policy for transformative change: innovation policy 3.0. *SPRU Science Policy Research Unit*. University of Sussex: Brighton, UK.
Schot, J., Steinmueller, W.E., 2016b. Framing innovation policy for transformative change: innovation policy 3.0. *SPRU Science Policy Research Unit*. University of Sussex, Brighton, UK.
Shortall, S., Byrne, A., 2016. Gender and sustainability in rural Ireland. In: *A Living Countryside?* (pp. 307-322). Routledge.
Steinke, J., van Etten, J., Müller, A., Ortiz-Crespo, B., van de Gevel, J., Silvestri, S., Priebe, J., 2020. Tapping the full potential of the digital revolution for agricultural extension: an emerging innovation agenda. Int. J. Agric. Sustain. 1–17.
Stilgoe, J., Owen, R., Macnaghten, P., 2013. Developing a framework for responsible innovation. Res. Policy 42 (9), 1568–1580.
Trienekens, J.H., 2011. Agricultural value chains in developing countries a framework for analysis. Int. Food agribusiness Manag. Rev. 14 (1030-2016–82778), 51–82.
Turner III, D.W., 2010. Qualitative interview design: A practical guide for novice investigators. Qual. Rep. 15 (3), 754.
Turner, J.A., Klerkx, L., Rijswijk, K., Williams, T., Barnard, T., 2016. Systemic problems affecting co-innovation in the New Zealand agricultural innovation system: identification of blocking mechanisms and underlying institutional logics. NJAS-Wageningen J. Life Sci. 76, 99–112.
Van der Burg, S., Bogaardt, M.J., Wolfert, S., 2019. Ethics of smart farming: current questions and directions for responsible innovation towards the future. NJAS-Wageningen J. Life Sci. 90-91, 100289.
Vanloqueren, G., Baret, P.V., 2009. How agricultural research systems shape a technological regime that develops genetic engineering but locks out agroecological innovations. Research policy 38 (6), 971–983.
Von Schomberg, R., 2013. A vision of responsible research and innovation. Responsible innovation: Managing the responsible emergence of science and innovation in society 51–74.
Von Schomberg, L., Blok, V., 2019. Technology in the age of innovation: responsible innovation as a new subdomain within the philosophy of technology. Philosoph. & Technol. 1–15.
World Bank, 2012. Agricultural Innovation Systems: An Investment Source Book. World Bank, Washington DC.
Zwart, H., Landeweerd, L., Van Rooij, A., 2014. Adapt or perish? Assessing the recent shift in the European research funding arena from 'ELSA'to 'RRI'. Life sciences, society and policy 10 (1), 1–19.