Designerly approaches for user involvement in the design of agricultural research

Jeske Margot Juliette van de Gevel

PhD

University of York

Theatre, Film, Television and Interactive Media

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Abstract

User involvement improves the efficiency, effectiveness, and scope of agricultural research processes. Yet despite four decades of exploring and developing methods for participatory research, it has never become mainstream in the agricultural technology development cycle. A case-study was undertaken with communities of smallholder farmers in Kenya and Tanzania to involve participants into a design process using a double diamond design framework. The case study examined how citizen science, being a new approach, impacts user involvement in participatory agricultural research. Furthermore, I explore the impact of participatory design tools and methods on farmer engagement in research using a *research through design (RtD)* approach.

The research in this thesis suggests that aesthetics and interaction design can flatten some of the hurdles to participation, however, this only partly tackles the issue of participation. A lack of understanding of the process and its indirect benefits in terms of research outcomes and learning, makes participants less inclined to participate in a meaningful manner, which indicates that scientific literacy is an important precondition for more engaged participation.

On a meta-level this research generates insights on the application of participatory design in low-income countries in terms of *how* we can involve users into the design of agricultural research. The discussion changes the perspective of the design of participation from its purpose or 'just how much participation is enough', to what can agricultural research do to design a experience that allows farmers to contribute to agricultural research in a meaningful way. Rather than seeing participation as a means to an end, exploring new ways to include users into the design of participatory processes might contribute to solving the 'problem' of participation. Last, the research reflects on the various roles that design practitioners can play in the context of agricultural research.

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Declaration

I, Jeske Margot Juliette van de Gevel, declare that this thesis is a presentation of original work and I am the sole author. This work has not previously been presented for an award at this, or any other, University. All sources are acknowledged as References.

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Chapter 1
Introduction

1.1 Introduction

Farmer participation is an important precondition of technology development to ensure that technologies developed to improve agricultural production are locally appropriate and used. Adaptive research is a common feature of the agricultural technology development cycle aimed to validate or adjust a new technology to the specific requirements of a particular area in terms of soil, climate, and environmental, social, and economic conditions (Njogu, 2012). Adaptive research requires a close collaboration of researchers and farmers in the technology development, since the exclusion of either of them increases the likelihood that the research process will result in unsustainable or undesirable technologies. In agricultural research adaptive research is often referred to as on-farm research to indicate a shift from technologies developed in 'the lab' to testing under field conditions. This does not imply that technologies are developed in-situ, rather the adaptation of existing technologies to local conditions. Adaptive research can take different forms from simply validating a technology or evaluating its impact to the participatory (co)design of technologies.

Four decades of experience in the field of participatory research in agriculture, has resulted in a large number of methods and examples on how to conduct participatory research with farmers and other stakeholders, however, it has never become the mainstream approach to technology development, mainly due to institutional, epistemic and practical difficulties in its implementation. More recently the use of digital technologies has pushed innovations in the field of participatory research further. Participatory modelling increased the efficacy and efficiency of research and development by using spatial representations which can change the way people interact and learn from each other (Naivinit *et al*., 2010; Barnaud *et al*., 2013; Etienne, 2014; Huang *et al*., 2018). Citizen science uses online participation and digital tools to enhance the ability and the scale on which to involve volunteers in scientific processes (Newman *et al.*, 2012; C B Cooper, Bailey and Leech, 2015). Whilst these recent approaches involve more diverse ways of distributing work across stakeholders and aligning these kinds of work with different types of motivation to participate, such alignment requires careful design of participatory projects. Project design in agricultural research remains the main task of scientists and only a handful of examples of co-design involving farmers in goal setting exists (Dogliotti *et al.*, 2014; Dolinska *et al.*, 2020). Here insights from participatory design, citizen science, and designerly ways of conducting the research could help to make the design of participation more explicit and open up a wider space of experimentation to creatively conceive and test different configurations of participation.

Central to the field of participatory design is the active involvement of users in design processes (Simonsen and Robertson, 2012). What started as assessments of the impacts of technologies in everyday life, has evolved into exploring how design and technology development can be used to understand what people do, not simply through asking but through processes of making or enacting (Chamberlain *et al.*, 2012; Simonsen and Robertson, 2012). Whilst user involvement in agricultural research is nothing new, participatory processes are mostly intended to appropriate or evaluate agricultural technologies or measure the impact they brought forward. Participatory design intends to bring together stakeholders to envision future states (the new) as part of the design process and does so by through mutual learning and co-realisation (Simonsen and Robertson, 2012).

This dissertation describes research conducted in rural communities in two locations in East Africa where tricot experimental trials were being implemented. The research explores how to involve users of the tricot approach into a design process using the tools and techniques brought forward from the field of participatory design. The research outcomes are expected to be valuable to agricultural researchers, who wish to engage farmers early on in the design process, before the actual research process has been developed to ensure that the subjective goals and preferences of participants in the research are included. The study generates insights on the value of designerly approaches for the development of participatory research in agriculture focusing on low-income countries. Many of the methods and tools used in this thesis have not been explored in this user context, therefore the outcomes of this study are of value to designers of participatory research.

1.2 Research questions

The research is guided by two questions:

How might we design more engaging participatory agricultural research that motivates farmers to participate?

The first aim of this thesis is to explore what features of the design of citizen science experiments can increase motivation for participation by farmers? Or how the use of design tools and techniques can be used to increase the engagement of farmers in a citizen science-inspired research process for technology evaluation. The work will build on a citizen science approach developed by Bioversity International applied to on-farm variety evaluation (see chapter 4) to explore issues around motivation and participation. In the tricot approach, a large number of farmers individually evaluate a different combination of three crop varieties. Feedback on these varieties is pooled and the results are shared back with farmers on paper and through group discussions. While tricot has seen first successes (van Etten *et al*., 2016), it remains unclear to what extent it does or can deliver on the full promise of citizen science, including increased scientific understanding and democratic participation in the research process on the part of the non-scientists, i.e. Farmers (Irwin, 1995). To answer the first research question, I set out to discover the drivers and hurdles of the tricot approach as an exemplary study by going through a more or less standard design process to determine the problem space and design and validate potential solutions that could improve the approach.

Participants have multiple and diverse motivations to participate in agricultural trials, including learning, social interaction and, to some extent, complying with expectations from field agents. According to Beza et al., (2017) who studied motivational aspects of participation in the *tricot* approach, an important factor influencing participation is the contact farmers have with field agents throughout the research process as well as the ability to benefit from trainings. The authors divide motivations into two categories: intrinsic motivations (*contributing to scientific research, wishing to help researchers, wishing to share information)* and extrinsic motivations (*wishing to network with experts or members of a community, wishing to pass time and have fun or expecting something in return)*. Taking into account the motivations of farmers could help to predict attendance and depth of participation during the course of the research. The amount of effort and time farmers are able to dedicate to the trial is limited and farmers strategically choose to participate in parts of the research that provide the most benefits to them. Similarly, researchers often choose different forms of participation for different research phases and 'jump between types of participation' (Johnson, Lilja and Ashby, 2000; Giessen and Nichterlein, 2005). This suggests that the design of participatory research should allow participants to take on different roles and participate with different intensities during the course of the research (Hauser *et al*., 2016; West and Pateman, 2016; Beza *et al*., 2017).

What is the value of using designerly methods in the development of participatory agricultural research?

The second aim of the thesis is to provide insights into the value of using designerly approaches. On a meta-level I reflect on the value of adopting a designerly approach to conducting participatory agricultural research. This resulted in an exploration of designerly approaches and how they can be applied in participatory agricultural research in low-income countries. A *Research through Design* (RtD) approach underlies the work presented in this dissertation (Stappers and Giaccardi, 2017). The research process is structured and carried out as a 'design process' and using design methods and tools as methods of enquiry. Adopting a case-study approach allowed reflection on the value of these methods and provided means of validation in terms of appropriateness in our user context. In a first design 'field' experiment we evaluated different prototypes for data collection and feedback delivery within our study area. We worked on the front end (communication towards the end-user) to see what gains we could make.

This study led to the discovery of a major hurdle that appears as a blind spot in the current citizen science discourse: existing literacy in the population, both scientific and numerical, is a precondition not necessarily for motivation or participation per se, but for any 'full' participation that goes beyond an extractive research-citizen relation, and assumes that participants can rely on basic research skills which enables them to understand the research process in a similar way researchers would. However, not every participant will have this understanding, and this might have consequences for how they participate in the research

and if this is extrinsically or intrinsically motivated. It might also influence the interest in the results of the trials beyond the comparisons made on participants' own farms.
A second design experiment was developed to measure if additional (or more *designed*) training could impact scientific literacy and if this in turn can impact levels of motivation. I used a pre/post-test design to measure levels of situational motivation, self-efficacy and research literacy before and after a training event. Perhaps rather unsurprisingly, we found that more training leads to better understanding and perceived self-efficacy. However, training might not necessarily have a measurable effect on participant motivation. This is in line with the literature on self-efficacy where self-efficacy is one's belief in the ability to undertake a task (which in our experiment has grown), yet doesn't make a statement about whether or not one has the intention of carrying out the task.

I used a mixed-methods approach combining designerly approaches with social science and experimental design. Design research and synthesis are used to study the user experiences in existing participatory approaches. Prototyping is used to experiment with form design and participatory formats to discover which variables afford more engagement and work better in low-literacy environments. Experimental design is used to measure motivation, self-efficacy, and research literacy before and after treatment. As a whole, the application of designerly approaches and co-design in a rural context in Kenya offers valuable insights for the design of participatory agricultural research and how to involve users in the process.

1.3 Thesis Structure

This thesis comprises a series of activities aimed to answer the key research question. Each chapter can be read as a stand-alone study consisting of detailed guiding research questions, methodology and results.

The first chapter presents the direction, goal and research process of this thesis.

The second chapter provides background information on participatory agricultural research. How did participatory agricultural research evolve from linear approaches to citizen science and what barriers remain? What are some of its challenges and recent innovations? We draw inspiration from participatory design to help counter existing barriers in participatory agricultural research.

In the third chapter, I provide an overview of the research approach and methods used and elaborate on a research-through-design approach that underlies this exploration. The fourth chapter introduces the tricot case study which serves as an exemplary model and describes its approach to research and the user context.

The fifth chapter presents findings from a user interview study on tricot implementation and describes the motivations and user experiences of its participants. It reflects on the benefits and hurdles (or constraints to fully participate) from a user perspective. The application of social science methods in combination with design methods uncovered the motivational, ability-related, and contextual drivers and hurdles for participation and the implications for configuring participatory research processes.

The sixth chapter describes the process of design synthesis; of using the insights generated in the previous chapter and translating all the original pieces of information into actionable design knowledge. I model the data by highlighting the current state and envisioning the future state. I reflect on the sense-making process to set the priorities for design and to demarcate the problem space.

The seventh chapter documents the ideation process in two steps. First, it presents precedent material that could inspire viable design solutions. And second, based on the design recommendations and precedent insights, I generate ideas for different design processes and prototypes. I also reflect on the choices made in the design process (which ideas we continue to work on and which we will leave for now).

The eighth chapter describes the design process of rapidly prototyping formats for data collection, feedback delivery and knowledge sharing and reflects on the inclusion of end-users in the design process.

The ninth chapter describes a second design experiment intended to explore whether a lack of understanding of the research process underlies a lack of motivation of participantsto collectg data and find value in the feedback on the results of the trials. I conducted an empirical study measuring motivation and self-efficacy before and after a single training event aimed to increase participants' understanding of the process to see if increased research literacy impacts participants' motivations.

The discussion chapter provides a synthesis of the previous chapters and presents the main findings of the research presented in this thesis, including what conditions lead to increased engagement of participants and why. It reviews the potential benefits of using designerly approaches for configuring participation in agricultural research. In addition, it suggests areas for further research.

Finally, chapter eleven returns to the research questions and draws conclusions based on the work presented in this thesis.

Chapter 2

Literature review

The work presented in Section 2.2 is published in Agronomy for Sustainable Development as 'Citizen science breathes new life into participatory agricultural research. A review' by myself in co-authorship with Jacob van Etten and Sebastian Deterding.

2.1 Introduction

Participatory research in agriculture has received considerable attention in the literature, in terms of its evolution and necessity, and perhaps even more so in terms of its challenges. In this literature review, I present the challenges in participatory agricultural research and illustrate how recent innovations in the field might help to overcome these barriers. The conceptual and methodological underpinnings of design and design research are briefly highlighted at the end of this chapter, as a primer for the research approach described in chapter 3.

2.2 Participatory agricultural research: from linear approaches to citizen science

2.2.1 The evolution of participatory agricultural research

Participatory research describes research that is done not only *for* or on but also *with* people. What sets it apart from conventional research is a deliberate, focused interaction between researchers and participants leading to changes in research design, technology development, and/or research evaluation (Ashby, 1996; Lilja and Bellon, 2008). While farmers have historically participated in all manner of agricultural research, farmer-participatory research became a specific focus in the agricultural sciences in the early 1980s. This stemmed from the recognition that farmers in marginal areas generally did not benefit from technological advances and thus that more effort should be invested into more inclusive approaches (Chambers, 1994b; Sumberg and Okali, 1997; Johnson, Lilja and Ashby, 2003; Biggs, 2008; Scoones, Thompson and Chambers, 2008). In farmer-participatory research, farmers would be involved directly in setting research goals, selecting seeds, observing pests and crop diseases, or evaluating research products. The expectation was that such participation would help to tailor research to the needs and criteria of participants, which would lead to new insights, products, and services that were more useful for their prospective target audience and would empower participants in the process (see Section 2 below). Farmer participation also offers legitimacy to agricultural research and aims to shift the paradigm of agricultural research from a linear transfer of technology toward more people-centred approaches revolving around innovation and learning. However, in reality, participatory research in agriculture did not live up to its promise, due to institutional and epistemic difficulties in its implementation. For example, in plant breeding, participatory styles of research are still evolving but have never become mainstream (Ceccarelli, 2015). Even in institutional contexts in which participatory exercises have gained legitimacy, their findings are not fully used (Sumberg *et al*., 2013).

Research is an essential part of the agricultural technology development cycle and involves selective breeding to identify and develop crop varieties, distribution, and promoting new varieties and inputs (Mcguire, 2005). Public sector organizations such as the CGIAR[1] carry out agricultural research and support the work of the national agricultural research system (NARS) on country level. Extension or agricultural advisory services are making scientific research and knowledge on agricultural practices available through farmer education mainly with the aim to increase productivity and alleviate rural poverty. The private sector focuses most of its research efforts on agricultural inputs such as seed, chemicals, pharmaceuticals and machinery, since this is where the majority of the commercial opportunities can be found. Large scale private sector players Bayer, Syngenta, BASF and Rijk Zwaan to name a few, carry out most of their research and development activities in developed countries and their products are developed for that particular market (Fuglie, 2016). Smallholder farmers in developing countries might have different requirements and are presently not served by the private sector. Modern technologies (improved varieties) are developed for use under specific conditions and management practices, which might be unattainable or too costly for smallholder farmers to adopt. Agricultural research has favored increasing the yield potential of crops over other traits such as taste, ease of processing and market value. In general, both public and private sectors have focused its efforts on increasing agricultural

[1] Formerly called Consultative Group on International Agricultural Research

productivity and this has led to criticism in terms of the impact of research and development for smallholder farmers.

In the 1960s, a shift in agricultural research led to the development and implementation of an increasing number of participatory research approaches. Researchers realised that technologies developed by agricultural research did not adequately address the needs of farmers and blueprint solutions often did not serve farmers who operate in complex, diverse and risk-prone environments. Similarly, in the development sector, disappointment about how much impact their projects actually made, inspired the design of more participatory processes. Since then the landscape of participatory research has changed dramatically. For agriculture, research shifted from 'on-station' research transferred to farmers to 'on-farm' experimentation and learning, and from researcher-driven, to more 'participatory' and eventually to 'client-driven' advisory services. Likewise, the place where agricultural research takes place has shifted from (international) research institutes and the national research system, to a more embedded system of research networks and innovation platforms targeting a larger group of stakeholders. This shift is exemplified by 'new' methods and approaches including participatory modeling, co-design or co-creation and citizen science with the intention to provide the tools needed to foster collaboration between farmers and researchers, e.g. Providing them with an interface to communicate even when their goals and ambitions might differ.

Agricultural research institutes on international and national levels have shown little capacity to learn from end-users and have historically favored technology adoption ('teach them') over adaptation ('creating diverse and location-specific products') as the latter required more resources and intensive collaboration with a wide range of stakeholders on the ground. Even in the current more client-driven field of agricultural research, focus lies on the *product* rather than on the *user*. This is shown by limited participation of the end-user in the agricultural technology development cycle and the use of generic tools and methods to solicit user inputs, particularly in areas serving poor client groups (Farrington and Martin, 1988; Sperling *et al*., 2001; Kiptot and Franzel, 2014). Here, we can greatly benefit from the insights in the field of product design and participatory design in terms of user involvement in the research process.

2.2.2 The promises of participatory agriculture research

The existing discourse on participatory research in agriculture highlights three major potential positive impacts: increased effectiveness and efficiency of the research process, empowering marginalised social groups, and improved environmental sustainability of developed solutions.

Increased effectiveness and efficiency

According to Johnson *et al.* (2004), participatory research can strengthen feedback links between researchers and participants, which lead to a better understanding of the problems, more appropriate solutions, and faster adoption. It takes into account farmers' constraints and contextual factors from the outset, rather than designing optimal technologies on research stations and then undertaking a process of adaptive research (Collinson, 2000). More generally, combining formal research and informal farmer knowledge practices can increase effectiveness by offering more appropriate solutions at local level (Sumberg, Okali and Reece, 2003; Hoffmann, Probst and Christinck, 2007). More efficiency can be achieved by outsourcing certain tasks to participants, and by avoiding separate research and adaptation phases. Yet up until now participation has been ad-hoc in its application in agricultural research. Agricultural researchers today still take the lead in setting the criteria for conducting research and create solutions in 'laboratories'. The participation usually comes afterwards when researchers are testing the technology or solution and need input from the end-users (farmers) in terms of impact assessments, adoption rates or monitoring and evaluation.

A more concrete example is the plant breeding work of Ceccarelli (2015) and others, who pioneered participatory approaches in the early 1990s by bringing formal breeding techniques to local communities. Conventional plant breeding tended to favor resourceful farmers who are able to modify their environments to accommodate the requirements of new crop varieties. Poor farmers operating in marginal areas often do not have the resources to apply fertilizers and other inputs and are risk-averse when it comes to testing out new and unknown varieties. By decentralizing plant breeding to on-farm selection, farmers can select and help to breed varieties that suit their specific environmental and social conditions and is arguably a better alternative to conventional breeding practices in the light of climate change adaptation for the rural poor (Ceccarelli and Grando, 2007, 2022). Conventional breeding processes involve several years of breeding varieties, followed by onfarm testing of these varieties. Participatory plant breeding moves selection to farms in earlier stages of the process, significantly reducing its duration (Johnson *et al.*, 2004). Experience has shown that involving farmers at the design stage leads to a faster and less expensive breeding process and higher adoption of new varieties (Ceccarelli, 2015).

Johnson *et al.* (2003) state that the initial costs for participatory research might be higher as they require to establish links with local communities and community meetings, but these additional costs are not significant. Thus, Neef (2008) looked at the costs of adding participatory approaches to conventional research processes, and found that the costs for hiring local staff and compensating farmers' time and travel costs made up only a fraction of the total. The range is 2.8% to 5.6% in three case studies. Additionally, the costs for compensating farmers can be offset by a decrease in costs for research when certain tasks are taken up by farmers. Working in remote locations increases logistics, mobilization, and communication costs (Chambers and Jiggins, 1987; Bentley, 1994), but scaling conventional research to multi-location trials and research efforts would incur similar increases without the benefits of participatory approaches (Morris and Bellon, 2004).

More farmer participation moves costs from researchers to involved farmers, requiring farmers' time, intellectual capacity, and sometimes also inputs such as land, labor, or assets (Morris and Bellon, 2004). Some participatory approaches require considerable amounts of time away from the farm, for example, participatory rural appraisal exercises where entire villages are required to participate in meetings over multiple days (Hoffmann, Probst and Christinck, 2007) or participatory plant breeding processes that require farmers' commitment at peak harvest times and usually cover multiple seasons (Collinson, 2000). However, there are few studies offering cost analyses from the farmer side (Gebreyes and Mattee, 2013; Vlontzos *et al.*, 2021). Farmers often calculate their opportunity costs to determine what they could earn if they used their time doing something else or continued participation at busy times in the farming cycle (Cornwall and Jewkes, 1995). Hence, their participation in participatory research can be read as an indicator that to them, participatory research is an effective and efficient use of their time.

One more general problem with cost-benefit analyses is that the gains of research are measured through a narrow focus on outputs, for example, the number of varieties released (Spielman and Kennedy, 2016). Impacts like increased farm income, technology adoption, or improved livelihoods are less often measured in cost-effectiveness studies. As Lilja and Bellon (2008) point out, the benefits of participatory research for farmers extend to more indirect forms, for example, increased knowledge, changes in agricultural practices, or obtaining enhanced skills, as well as facilitating joint learning between researchers, farmers, and other actors. These benefits are not easy to measure using standard impact assessments, and their value is often not considered. Emerging approaches attempt to document this wider range of benefits, using a mix of different methods, including participatory ones (Faure *et al.*, 2020).

Empowerment

A main motivation to engage participants in agricultural research is empowerment (Sumberg, Okali and Reece, 2003). Some authors state that participatory research can enable marginalised groups in society to make their own decisions by equipping them with basic research skills or by giving them a voice in decision-making processes (Bunch, 1982; Chambers, 1994a; Cornwall and Jewkes, 1995). Several authors frame empowerment in terms of redressing some existing inequality, be it between different social groups, between researcher and farmer, or between different groups among farmer participants. For Bunch (1982), any intervention needs to consider the different socio-political rights of different groups within society; otherwise, interventions might reinforce existing inequalities and increase the power of the elite. This is further detailed in Toyama's amplification theory for ICT4D (2011) which shows that technology might amplify existing inequalities and missing institutional capacity. For Chambers (1994a), empowerment requires a change of role for the researchers to equip farmers with the tools to do their own appraisals and needs assessments. He states that researchers should develop methods that allow farmers to participate in a non-extractive way. Another theme that is often mentioned is cognitive justice. Cornwall and Jewkes (1995) state that "ultimately, participatory research is about respecting and understanding the people with and for whom researchers work. It is about developing a realization that local people are knowledgeable and that they, together with researchers, can work towards analyses and solutions" (Cornwall and Jewkes, 1995; p. 1674). While participation can empower farmers and other participants, it can empower researchers as well. Farmers' voluntary participation and their sense of ownership in research processes can be a form of legitimization for research and its institutions (Ashby, 1996; Johnson *et al*., 2004; Lilja and Bellon, 2008).

Empowerment depends on the ability of participatory activities to be inclusive in terms of recruitment and creating space for people to express themselves. Inclusion spanned across socioeconomic status, location, gender, cultural norms, or poverty (Johnson, Lilja and Ashby, 2003; Cornwall, 2008; Waddington *et al*., 2014). Participation of women in agricultural research tends to be lower than that of men (Cornwall, 2008; Pope, 2013). This can be related to male-dominated mixed meetings in which women's voices remain limited (Joseph and Andrew, 2008), explicit targeting of organised or literate farmers (Phillips, Waddington and White, 2014) or cultural sensitivity, for instance targeting married women only (Najjar, Spaling and Sinclair, 2013). Larger scale or more innovative farmers are more likely to enter participatory research due to selection criteria of extension agents or farmers' self-selection (Anderson and Feder, 2004), as well as confidence levels from previous experience in participatory research (Johnson, Lilja and Ashby, 2003). The design of the intervention or the composition of the research team can influence social inclusion through the quality of communication or social distance between researchers and farmers (Sumberg *et al*., 2013, p.253; Trimble, Araujo and Seixas, 2014) or the timing and duration of activities, which can disproportionately affect participants who are time-poor (Chambers, 1994a; Hoffmann, Probst and Christinck, 2007). Exclusion effects may be partially overcome by carefully deciding selection criteria and recruitment strategies beforehand (Friis-Hansen, 2008). Also, carefully selecting formats of participation can activate mechanisms of social inclusion. Deliberate participation ("talking") through group discussions, for example, can exclude marginal voices due to leadership effects, while performative participation ("doing") can generate alternative spaces for expression (Richards, 2007). Even though participation in agricultural research does not automatically empower farmers, there is broad agreement that appropriate participation is necessary if agricultural research is to contribute to empowerment.

Sustainability

Ashby (1996) suggests that even though participation may make technology development more efficient, a more important positive impact is improving the environmental sustainability of developed innovations. To avoid further environmental degradation, researchers should always consider the long-term effects of the technologies they develop on future generations (Collinson, 2000). Researchers and farmers operate in different realities; hence, adoption of technologies without adaptive research and/or stakeholder participation can lead to unsustainable solutions (van de Fliert and Braun, 2002). Furthermore, participation can help to create a sense of ownership over the technologies or the research process, which means that people will be more inclined to look after them if it serves their interests (Hickey and Mohan, 2004). Involving participants in research also increases sustainability because it avoids creating dependencies on outsiders to keep offering benefits (White, 1996; Cornwall, 2008).

New approaches have attempted to further decentralise innovation processes and decrease the dependency on a few central actors and create broader involvement of a range of stakeholders, including public and private organizations (Klerkx, Mierlo and Leeuwis, 2012). Farmer-led research supported by civil society organizations attempts to make research unambiguously oriented to farmers' needs (Waters-Bayer *et al*., 2015). Innovation platforms have attempted to embed participatory research in broader processes of innovation to move away from technology-focused approaches to more system-focused approaches. Innovation platforms bring together individuals and public and private sector organizations and institutions for priority setting, networking, learning, negotiating, and experimenting, with the aim of building up long-term engagement between stakeholders to achieve more development impact (Schut, Cadilhon, *et al*., 2016). Even though these approaches have broadened the range of stakeholders beyond farmers, farmer-participatory approaches are a crucial ingredient to support the sustainability of the change these approaches are expected to bring.

2.2.3 Why has participatory research not lived up to its promises?

Participatory research has successfully created "farmer-centric" approaches to developing agricultural technology, for example, through the development of farmer innovation networks (Waters-Bayer *et al*., 2007; Abrol and Gupta, 2014), market-led development, participatory approaches to learning and impact assessment (Douthwaite and Hoffecker, 2017; Heinemann, Hemelrijck and Guijt, 2017), and farmer-to-farmer innovations (Van Mele, 2006; Kiptot and Franzel, 2014; Chowdhury *et al*., 2015). These approaches have responded to the changing role of farmer organizations (Hellin, Lundy and Meijer, 2009; Ton *et al*., 2014) and the development of more demand-driven extension services (Aker, 2010; Humphries *et al*., 2015) and are embedded in more integrated approach toward agricultural research through multi-stakeholder innovation platforms (Schut, Cadilhon, *et al*., 2016; Douthwaite *et al*., 2017; Pigford, Hickey and Klerkx, 2018). At the same time, co-design of farming system approaches has emerged (Meynard, Benoit Dedieu and Bos, 2012; Berthet, Hickey and Klerkx, 2018) and participatory modeling and simulation approaches have made innovative contributions (Naivinit *et al*., 2010). Despite this proliferation of approaches, we observe that they remain still unconnected to much biophysical research in agriculture in national and international research organizations. This lack of mainstreaming needs to be explained. Two major issues emerge from the literature: the institutional and epistemic workings of agricultural research and misalignment of participatory configurations and innovation around participation itself.

Entrenched scientific institutions and incentives

One well-evidenced barrier to mainstreaming participatory research has been the institutional workings of science itself. Waters-Bayer et al. (2015) describe how a lack of effective institutional learning and knowledge management processes keep formal research institutions, in particular the CGIAR (formerly the Consultative Group for International Agricultural Research), from learning from end users (see also Kristjanson and Harvey, 2014). For international rice research, Sumberg et al. (2013) found that some participatory research formats, such as participatory variety selection, had found legitimacy but that there were no clear, established ways for their findings to inform research decision-making. Similarly, Becker (2000) describes a perpetuation of standard epistemological practice at strategy level where research priority setting tends to follow a natural sciences approach, "with a few ingredients of social sciences" (Becker, 2000, p.5). The short-term nature of most participatory projects, the low number of scientists and managers that have experience in participatory research, a reward system which favors data production over impact, and the lack of exchange and learning opportunities on the topic of participatory research are further institutional barriers affecting international agricultural research centers and the national agricultural research systems in developing countries. The scientific value of participatory research is sometimes questioned because of its perceived lack of precision, control, replicability, and generalizability (van de Fliert and Braun, 2002). Standard methods of collecting feedback, such as surveys, technology evaluation, and field visits, are insufficient to generate useful user feedback, and experiences, opinions, and knowledge from extension officers and farmers are rarely documented or used to validate results, underestimating their value. Further, it often takes more time to set up participatory forms of research and get participants involved, and therefore results also take longer.

These institutional and epistemological barriers are in turn perpetuated by several other systemic issues of agricultural research. First, competition between institutions and individuals for funding and academic merit prevents sharing data and learning experiences and generates a culture of knowledge hoarding (Hoffmann, Probst and Christinck, 2007; Schot and Geels, 2008; Abah *et al.*, 2011; Pope, 2013; Waters-Bayer *et al.*, 2015). Second, high staff turnover inhibits the uptake and transfer of "new" participatory approaches (Johnson, Lilja and Ashby, 2003). Third, research incentives are not connected to accountability toward end users (Schut *et al.*, 2016b). Fourth, staff performance management lacks appropriate mechanisms to incentivise scientific workers to deliver end-user impact (Anderson and Feder, 2004). Thus, as research systems move to higher accountability and client orientation, participatory research may become stronger (Sumberg, Thompson and Woodhouse, 2013).

Lacking research and innovation around participation itself

A second barrier to mainstreaming is lacking reflexive research around participation itself. In areas of agricultural research in which participatory methods were first applied, one finds a limited and relatively static repertoire of participatory methods in use (Sumberg, Thompson and Woodhouse, 2013). This extends to the way participation itself is conceptualised. Many authors stay close to Arnstein's (1969) "Ladder of Citizen Participation" (Biggs, 1989; Pretty, 1995; Lilja and Ashby, 1999), see figure 1. Arnstein classified citizen participation according to the degree of power of citizens in decision-making processes, from nonparticipation through tokenism to true citizen participation. Biggs (1989) similarly describes four modes of participation in agricultural research as *contractual* (farmers are hired to participate in experiments or provide land), *consultative* (farmers' opinions are sought to plan interventions), *collaborative* (researchers and farmers work together in researcher-designed projects), and *collegiate* (researchers and farmers work together as a team to strengthen the informal research system). Lilja and Ashby (1999) later added a fifth mode of farmer experimentation: farmers experiment independently without interference or instruction of researchers. In these categorizations, variation in participation is generally plotted along a single axis of relative power or influence of researchers versus farmers. Arnstein's Ladder and derived categorizations imply a normative stance—more and more "genuine" participation is always better (Neef and Neubert, 2011). It is telling that few have tried to develop more sophisticated perspectives on farmer participation or engage more directly in designing new participatory methods (Neef and Neubert, 2011). The noncanonical status of participation and its highly normative conceptualizations seem to have led agricultural researchers to take participatory formats "as a given," focusing on their legitimation and adoption, rather than their selective and dynamic adaptation to different contexts.This might result in the rigorous application of 'formats' rather than adopting the underlying idea and (re)designing the approach to suit its application context.

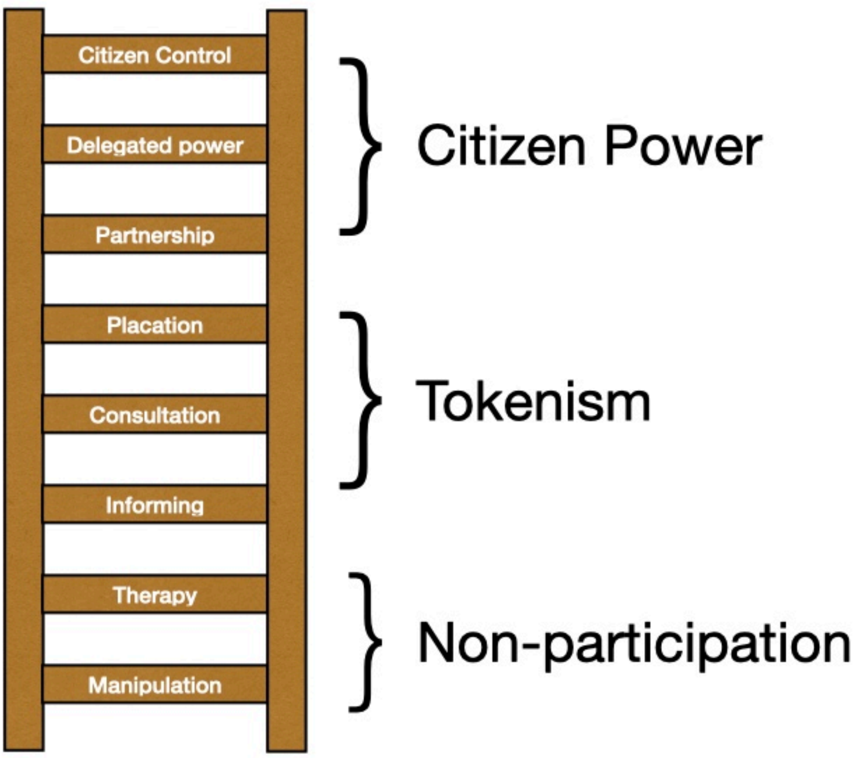


Figure 1: Typology of eight levels of participation (Arnstein, 1969)

This contrasts with digital technology design, where researchers critically examine participation and deliberately and playfully explore and evaluate new methods for participation. Mccarthy and Wright (2017) point out that Arnstein's Ladder is of limited value in participatory design contexts (in which participatory technology development in agriculture can be included), as it originated in public participation in a type of policy decision-making where relatively well-defined questions need to be answered. In design processes, in contrast, participation can and should take place in multi-dimensional, dynamically changing constellations of agency, control, self-determination and power, addressing, and often reframing ill-defined, significant problems. This has led them and many others to explore alternative formats for configuring participation suited to the particular needs and contexts of different projects.

2.2.4 New configurations of participatory agricultural research

Renewed innovation and reflection around participatory research have influenced some areas within agricultural sciences much more than others. The static situation observed by Sumberg et al. (2013) seems to be applicable especially to those areas that generate data through field experiments and observational studies. The explanation advanced above is that a conceptual deficit around participation persists across the agricultural sciences and has impeded a more versatile design of participatory approaches. One innovative impulse may come from participatory approaches around involving users in design processes using co-design and systems modelling. Citizen science provides another impulse to rethink participation in agricultural research.

Citizen science

The term “citizen science” has emerged in the past 30 years to describe new forms of participatory research across a wide range of disciplines,

Commonly enabled by new digital technologies (Irwin, 1995; Bonney, 1996). There is no universally agreed-upon definition. In fact, several researchers stress that the plurality of understandings is critical to the creativity and innovation found in the field (Schäfer and Kieslinger, 2016; Eitzel *et al.*, 2017; ECSA, 2020). For instance, while Cooper et al. (2007) define citizen science as “a dispersed network of volunteers to assist in professional research using methodologies that have been developed by or in collaboration with professional researchers”, other authors indicate that any scientific work undertaken by members of the general public should be considered citizen science, as long as it aims to follow protocols which align with standard practices within the discipline in which the research is framed

(ECSA, 2020). These broad definitions do not allow us to distinguish citizen science in any clear-cut way from participatory action research and participatory monitoring which have a longer history in the agricultural sciences. Nevertheless, the efforts that are labeled “citizen science” are distinct in their genesis and form. Citizen science allows researchers to benefit from scientific work generated by the public, and members of the public to be involved in authentic scientific activities, for example, modeling, collecting research data, and experimentation. This sets it apart from other forms of the public engaging with science, including informal or volunteer learning (Jordan, Ballard and Phillips, 2012; Bonney *et al.*, 2016), public engagement with science (mccallie *et al.*, 2009) or public understanding of science (Bonney *et al.*, 2016).

The term citizen science can also be used to emphasise the social responsibility of science and a fitting democratization of science: to serve and be accountable to the public good; common people should be included in research processes or enabled and organised to conduct their own research (Irwin, 1995; Riesch and Potter, 2014; Dickel and Franzen, 2016). This corresponds to already-mentioned notions of empowerment in participatory research, not only through participation but also through an emancipation of science from its institutional context and as the sole responsibility of scientists (Woolley *et al.*, 2016).

Beyond its conceptual diversity, citizen science involves distinctive new elements or styles of research and participation that were absent or weak in previous participatory research, enabled by internet platforms, mobile phones, and other information and communication tools (icts) fostering computer mediated communication, networking, and collaboration (Dickinson *et al.*, 2012; Minet *et al.*, 2017). Specifically, it makes use of so-called *social computing* formats and tools, for example, prediction markets, reputation systems, crowdsourcing, collaborative editing and filtering, and distributed sensing (Knol, Spruit and Scheper, 2008). Bonney et al. (2016) show that internet technologies have made public engagement in scientific research more accessible and widespread in its ability to recruit large numbers participants and volunteers, including marginal groups. Large and complex datasets can be made available for piecemeal processing and analysis by many separate individuals online. As a result, digital tools have changed the scope of volunteer participation, enhanced the potential spatial and temporal coverage of data collection (mccormick, 2012; Solli, Wilson Rowe and Yennie Lindgren, 2013; Fuccillo *et al.*, 2015) and improved data and image analysis (Crall *et al.*, 2011; Caren B. Cooper, Bailey and Leech, 2015).

In the context of citizen science in agriculture, the term “citizen” refers to farmers and members of the public involved with agriculture “who actively contribute to science with their intellectual effort or surrounding knowledge or with their tools and resources. Participants provide experimental data and facilities for researchers, raise new questions and co-create a new scientific culture” (Green paper on Citizen Science, 2013). Citizen science in agriculture is a small but growing practice (Minet *et al.*, 2017; Ryan *et al.*, 2018). Agricultural research occupies a small percentage of the total effort dedicated to citizen science, with less than 2% of peer-reviewed articles reported to combine the term citizen science and agriculture (Ryan *et al.*, 2018). Citizen science has proven efficient to collect observations from farmers and other nonprofessionals through digital “crowdsourcing” approaches (Minet *et al.*, 2017). For example, plantvillage uses digital tools to improve smallholder farming, involving different efforts to monitor pests and diseases in agricultural crops (https://plantvillage. Psu.edu/). Similarly, large-scale on-farm experimentation is being done through citizen science format focused on crop variety evaluation (van Etten *et al.*, 2019; also see https://climmob.net).

Citizen science is considered attractive because it can lead to a “double win,” supporting more efficient and effective scientific knowledge generation for researchers while supporting learning for participants and their wider communities, accompanied by a greater social accountability of scientific research (Shirk *et al.*, 2012; Caren B. Cooper, Bailey and Leech, 2015; Bonney *et al.*, 2016). As for the first win, more effective and efficient scientific knowledge generation, digital forms of data collection can yield higher-quality data (in terms of spatial and temporal coverage and immediacy) at reduced costs (Blaney *et al.*, 2016). Data quality has been the subject of debate in much of the early literature around citizen science. Critics indicated that using data from non-scientists called for more extensive data verification. However, the possibility of generating high quality data through citizen science is accepted in several fields (Caren B. Cooper, Bailey and Leech, 2015). Besides the initial investments in program development, software development, advertisement, recruitment, and training, costs for citizen science projects tend to decrease over time. After a program is established, with relatively high initial costs, it is mostly the relatively low running costs for computing and networking that remain (Palmer *et al.*, 2017). The second win emphasises the educational value of citizen science. Learning takes different forms. Participants gain new skills or content knowledge (Brossard, Lewenstein and Bonney, 2005; Evans *et al.*, 2005), improve scientific literacy or understanding (Trumbull *et al.*, 2000; Jordan *et al.*, 2011), connect deeper with their environment (Newman *et al.*, 2017) or with other people (Bell *et al.*, 2008), and enhance environmental stewardship (Evans *et al.*, 2005; Ballard, Dixon and Harris, 2017). Some authors emphasise learning as a more interactive process, taking on board the perspectives of participants. Citizen science engages participants in decision-making processes (Shirk *et al.*, 2012) and addresses local community concerns (Middleton, 2006; Ottinger, 2010). These different benefits of citizen science closely match those of participatory agricultural research.

The goals and benefits of citizen science and its diversity may create the impression that citizen science is little more than a new label for participatory research. But even though there are important areas of convergence, citizen science shows some important differences. These not only reflect new methodological possibilities afforded by digital technologies but also the origin of citizen science, which emerged predominantly from rich economies and academic natural science research. Participatory agricultural research, in contrast, originated largely in and around applied agricultural research focusing on poor rural areas. In this sense, the differences between citizen science and participatory agricultural research are arguably not only scientific but also social. These differences in origins and trajectories make it interesting to explore possible ways to cross-fertilise between the two areas.

Participatory approaches for systems modeling

In some areas of agricultural research, innovative experiments with alternative forms of participation have taken place, especially around farming systems' research and design. Interactive models of leadership sharing between farmer researchers and scientists have become more common (Drinkwater, Friedman and Buck, 2016). Participatory modelling techniques have been developed to include different types of knowledge and values into decision-making processes (Berthet *et al.*, 2016). These methods involve different forms of participation, such as the co-design of simulations using role-play and gamified formats to explore possible scenarios in agriculture and natural resource management (Barreteau, O. *Et al.*, 2003; Martin, Felten and Duru, 2011). Combining multi-agent systems with role-playing games for research purposes has led to the development of companion modelling, sometimes referred to as the commod movement. Serious games are used to explore scenarios, for example Guyot and Honiden (2006) who use the companion modelling approach for computer-mediated interactions or Castella (2016) who used an agent-based spatial computational model in combination with participatory GIS and role-playing to predict land-use changes. Martin et al. (2011) developed a game-based approach to co-design farming systems called 'forage rummy'.

However, few have included stakeholders in the whole design process from problem identification and parameter setting to assessments of the model (Voinov *et al.*, 2016). These modelling approaches have led to more reflective ways of thinking about participation. Reflecting on a companion modelling exercise, Barnaud and van Paassen (2013) show how effective empowerment involves dealing with important dilemmas between empowering stakeholders to lead the process and strategic interventions to ensure that less influential stakeholders also have a voice. They contend that a neutral posture is impossible in this context and indicate the need for a "critical companion" posture that involves deliberate design choices in shaping participatory processes, whose objectives and assumptions are made explicit to participants. While this approach does not steer free of new dilemmas and questions, these types of reflections and approaches clearly go beyond the type of simplistic normative stance described above.

2.2.5 Novel aspects around participation

Four novel aspects around participation that have emerged as part of these new experiences. First, it has brought new attention to the study of participants' motivations. Secondly, the complexity of citizen science projects has led to fresh thinking on how participants can take up different roles in projects. Thirdly, an emphasis on learning has led to different ways to design and evaluate projects. Lastly, citizen science and other recent approaches have made use of digital tools to support the experience of participants. These experiences can provide opportunities to rethink participation in agricultural research and shed new light on its "empowerment agenda."

Motivating participation

The literature on volunteering makes fine-grained distinctions between the different factors that influence participants' motivation in different phases and roles and how this relates to the characteristics of participants (Clary *et al*., 1998; Grube and Piliavin, 2000; Penner, 2002; Piliavin and Callero, 2002; Unell and Castle, 2012; van Ingen and Wilson, 2017). Crowston and Fagnot (2008) distinguish between initial, sustained, and meta-contributors. Initial contributors are driven by curiosity, in combination with having time available to contribute and feeling confident in their expertise and self-efficacy. Sustained contributors are motivated by feelings of fulfilment or obligation to the project, in addition to intrinsic motivation in completing the tasks or by the feedback received from the activities or from other participants. Meta contributors go beyond what is to be expected from volunteers and can help with building up the research. They are driven by a sense of group belonging as well as responsibility toward the group to participate fully as well as by intrinsic motivation from the activities. There is empirical support for the relevance of this classification of contributors. Jennett et al. (2016) find that initial motivation to participate is driven by curiosity and an interest in or wish to contribute to science. However, sustained participation depends on continued interest, a "feeling they had aptitude for the task", as well as establishing a "rhythm of working." Participants develop their skills by participating on a regular basis, which makes participation also more rewarding. It also increases the opportunities for social engagement. Motivations also tend to change over the lifetime of participants.

Some authors choose to group volunteers in terms of their consistency in volunteering: constant volunteers have volunteered consistently throughout their adult lives, serial volunteers have volunteered intermittently, and trigger volunteers have only started volunteering after retirement for example (Hogg, 2010). Geoghegan et al. (2016) found that sustained volunteering depended on the ability to develop skills or gain knowledge and how much project feedback and communication were appreciated. This is echoed by Rotman et al. (2012), who see egoism as the main reason for engagement in citizen science projects in terms of personal curiosity, previous engagement, existing hobby and affiliation with the subject, or gaining experience. Secondary to this are motivations driven by recognition or attribution, feedback, community involvement, and advocacy. Differentiated motivation factors can also be correlated with socioeconomic factors. Frensley et al. (2017) found that prior experience in participatory research and a higher gross income are drivers for sustained participation. People tend to drop out due to time constraints and a perceived lack of ability to use online tools. Eveleigh et al. (2014) argue that "super volunteers" (who contribute much time) are important, but "dabblers" (casual volunteers) also need to be engaged. Generally, there are limited numbers of super volunteers, but large number of dabblers and drop-outs who give up after their initial participation yet remain interested. They argue that participatory projects should make space for both types of volunteers and approach them in different ways. They indicate the need to design for multiple points of entry without "forcing individuals into a sustained commitment" (Eveleigh *et al.,* 2014, p.2992) by encouraging them to gradually increase their contribution, emphasizing the liberty of choice of participants, designing small tasks, using feedback loops to raise interest in the project, or making former participants reconsider joining again. Nov, Arazy and Anderson (2014) show that tapping into extrinsic forms of motivation of volunteers might be useful too, as the quality of contributions is mostly affected by collective motives or social norms and reputation.

Citizen science has sparked new research on the motivation and level of engagement of participants. One of the distinguishing features of citizen science is the active involvement of citizens in scientific research with mutual benefits for both the scientists and the citizens (Robinson *et al.*, 2018). Citizen science projects have often relied on the intrinsic motivation of participants (and rarely payment) and relatively open forms of (online) recruitment (Crowston and Fagnot, 2008). The volunteer nature of citizen science participants and the shift away from monetary compensation makes a more reciprocal perspective obligatory, and sharpens the question how to attract, engage, and retain participants (Cooper and Lewenstein, 2016). Hence, researchers have felt a strong need to understand why participants join and keep contributing to citizen science projects, leading to findings that are inspiring for participatory agricultural research as well. Geoghegan *et al.* (2016) and Frensley *et al.* (2017) found that a contribution to science, sharing knowledge, and an interest in conservation were the main motivational factors to participate in environmental citizen science projects. Hobbs and White (2012) found that personal benefits such as learning, enjoyment, as well as health and well-being are driving motivations in wildlife monitoring. They report that bird tracking could even alleviated symptoms of depression. Dehnen-Schmutz et al. (2016) asked British and French farmers about their willingness to contribute to agricultural research as citizen scientists. Relatively few farmers deemed financial compensation to be essential, but this differed between tasks related to observation and data collection (where 9–18% rated financial compensation as essential) and tasks that involve experimentation (37%).

Beza et al. (2017) studied the motivations of farmers to contribute to tricot trials in India, Honduras, and Ethiopia. The ability to contribute to scientific research and an interest in sharing information were found to be the most important factors. When farmers were asked about what they expected in return for participation, they generally mentioned information and technical advice, and rarely mentioned monetary compensation. These findings imply that creating mutual benefits that trigger intrinsic motivation rather than external forms of motivation (e.g. Financial compensation or rewards) are an important factor in participatory research design.

Role differentiation

Another contribution of the recent developments in participatory research is that it has explicitly addressed questions of differentiated participation in more nuanced ways. Riesch and Potter (2014) write that it is not realistic to expect regular attendance or continued participation over prolonged periods of time, given the voluntary nature of participation. Participation in all stages of a project is still widely held as an ideal but differentiated conceptualizations of participation have become prevalent. An important impulse comes from the use of digital data collection techniques. Internet-based forms of participation using crowdsourcing formats can be relatively small scale and passive on the part of an individual volunteer but make substantial contributions to scientific research and benefit both the user and the researcher. Haklay (2013) indicates that in citizen science projects, different levels and roles of participation are regularly being combined. For example, contributors can start with a doing small crowdsourcing tasks and as they contribute more, move up in their level of participation and in consequence acquire more and different project roles. There is evidence that the level of participation does not correlate in a straightforward way with the impact of the work. Phillips (2017; Phillips *et al.*, 2019) and colleagues studied levels of engagement in several citizen science projects. They found that even though participants of co-created projects—which would rank higher in a "participation ladder"—engaged in more activities than participants in (lower ranking) contributory or collaborative projects, this did not necessarily lead to increased motivation or deeper learning. Deep learning is possible in any project, as participants learn differently and engage with the project in unplanned ways (see also Edwards *et al*., 2019).

From the practical perspective of designing participatory projects, Purcell, Garibay and Dickinson (2012) indicate that projects should cater for *multiple points of entry* by offering experiences for different comfort zones. This is linked to insights on how motivation can dynamically change over time but also to different levels of skill or cognitive ability of participants. For example, participants in citizen science projects are not necessarily non-scientists, but can be professional scientists who contribute voluntary in their free time (ECSA 2020). Differences in experience or familiarity with research processes can be found in any sample of participants and require strategies to ensure that learning is supported by materials catering for different groups, as their abilities to participate in terms of time, labor, or learning needs are likely to differ. Not every actor needs to be involved in scientific research at the same level or needs to attain the same learning goals. Participatory projects should set learning outcomes that cater for different forms and levels of participation. Science, according to Purcell et al. (2012), should be one of the many resources that individuals can draw upon to make informed decisions.

In participatory agricultural research, approaches did generally not assign differentiated roles and justify this differentiation in a positive way. Role differentiation is mainly associated with lead-farmers who have group leadership roles and facilitate peer-to-peer learning. The work on participatory modeling and simulation forms an exception to this with approaches designed to take diverging interests into account (Farrié *et al*., 2015; Berthet, Hickey and Klerkx, 2018). Thinking about participation as a collective, distributed effort with differentiated roles, also in observational and experimental work, opens a new spectrum of possibilities for research design. This can be an impulse for innovation in participatory agricultural research. Here, agricultural research can again take a page from the book of fields like human-computer interaction, where Vines et al. (2012) advocate for a lightweight and flexible approach to participation with room for configuring multiple levels of contributing. It serves as a call for the researcher to acknowledge and be flexible about the boundaries they set for participation, as multiple forms of participation are likely to occur naturally within participatory processes (Vines, Clarke and Wright, 2013).

Changing accountabilities and challenging epistemologies

Participatory research can fulfil its democratizing function through mobilizing an extended peer community of stakeholders (Funtowicz *et al*., 1997). This can challenge but ultimately enrich mainstream science, as the success of modern science depends on epistemic pluralism (Leonelli, 2007). Digital tools, such as cheap sensors and social media, can afford new ways of social mobilization around knowledge, which can then feed new epistemologies, most visible in citizen science driven by activist objectives. In a paradigmatic example, Ottinger (Ottinger, 2010) found that citizen scientists using cheap air quality sensors successfully challenged scientific standards, measuring and establishing the scientific and practical relevance of aspects of air quality that were overlooked by scientists—thereby actively holding professional scientists accountable for their current practice and its consequences for human health. Voinov *et al*. (Voinov and Bousquet, 2010; Voinov *et al*., 2016) provide examples of participatory modelling as a tool to enhance collaborative learning and decision making. Recent advances in social media and web applications have changed stakeholder participation in research processes, for example by using visualization and games to enhance the experience for participants. The authors also indicate that "citizens are less in awe of experts and external authorities" (Voinov et al., 2010, p. 196) and thus are more inclined towards claiming a space for participation, especially in the light of social changes such as climate change and environmental degradation. The article furthermore acknowledges the importance models have in their ability to change human behaviour and therefore their importance in usage for stakeholder participation (or co-innovation).

Frickel *et al*. (2010) unpack how citizen science can address "undone science," which they define as "areas of research that are left unfunded, incomplete, or generally ignored but which social movements or civil society organizations often identify as worthy of more research". Citizen scientists can go beyond advocacy for a shift in scientific priorities and enact this shift themselves, which empowers them to question existing epistemic biases on the basis of new data. In the case described by Ottinger (2010), the citizen science effort did not only produce new data itself but also had an impact by spurring new professional science efforts with new methods to address the questions raised by the measurements of citizen scientists.

Digital technologies for data collection and communication

A crucial new element in this is that cheap sensors and digital connectivity have made "big data" participatory science possible. Big data does not only imply a quantitative shift (more data) but also an epistemic shift in data interpretation, adapting the methods to take advantage of "opportunistic" data that is collected without following standardised sampling procedures, but sampled following the possibilities and interests of volunteers (Kelling *et al*., 2015; Ojha, Misra and Singh, 2015). In agriculture, it was precisely the rise of modern statistics (focused on small sample experiments) in the first half of the twentieth century that moved farmer-participatory experimental research to the background, as randomization practices were unpractical for farmer experimentation (Parolini, 2015).

2.3 Design methodology and practice

2.3.1 Design methodology

The desire to establish design as a discipline started in the 1920s with designers such as Le Corbusier advocating for a less artisanal and more systematic approach to the creation of new objects. Initially, design theorists looked to incorporate elements from scientific research and include these into design processes (Cross, 2011; Dorst, 2011; Kimbell, 2011). The 'design science movement' of the 1960s advocated to base the design process on objectivity and rationality (Archer, 1968; Rittel, 1972; Alexander, 1973; Jones, 1980; Cross, 2001). For example, Bruce Archer's 'Systematic Method for Designers' served as a checklist model of a design process. John Chris Jones ascribed the emergence of technical developments in computer systems to a trend of more logical and systematic approaches in design. For Christopher Alexander, a well-known architect whose "Notes on the Synthesis of Form' (1973) markedly influenced design theory, design consists of form and context. Form is "the process of inventing things which display new physical order, organization, form, in response to function..." and the form ultimately presents the solution to the problem. The context is what defines the problem.

Most of the aforementioned authors of the design methods movement changed their views significantly a decade later (Langrish, 2016). John Chris Jones and Christopher Alexander both concluded that a 'toolkit of rigid methods that obliged designers and planners to act like machines' would be detrimental to design practice (see Jones, 1980). Studying the work processes of engineers, he noticed that especially early in the design process their approaches relied on intuition, rather than solely using a rational process. A discourse on whether it is useful to separate design research from design practice started to emerge after the practicality of applying scientific methods to design processes showed limited evidence of working in practice (Cross, 2001). Rather than applying the scientific method, there was a need to distinguish between scientific research and design research. Rowe (1987) indicates that for most designers it is the hunches and presuppositions that drive innovation. Rowe describes this as an episodic process where designers interpret and relate to a situation with their own experiences, personal intentions, and prejudice. The situation itself is a combination of political, economic, social, logistical, technical, and aesthetical concerns (Rowe, 1987, p.34 and p.76). For Kimbell (2011a) this is only one way of looking at design. She highlights an important aspect of design that doesn't always constitute *making things* or creating systems, but *affording things* and creating a 'desired state of affairs' (Kimbell et al., 2011a, p.291).

2.3.2 Design practice

Then there is the *practice* of design. The approaches designers have to manage and conduct their work. It can refer to the actual practicing of design, a so-called 'designerly way of dealing with things', or refer to the design context, e.g. The practice of designers. Kimbell (2011a) defines design practice as "a situated, contingent set of practices carried by professional designers and those who engage with designers' activities" (Kimbell, 2011a, p.286). She distinguishes between design as *giving form* and design as *solving problems,* for example, designing to address complex societal challenges (Bijl-Brouwer and Malcolm, 2020). Nigel Cross studied design practices and the 'design ability' of professional designers (Cross, 2001, 2011). He sees the ability of designers to solve problems as a distinct feature of design that doesn't have an equivalent in the natural sciences or humanities. Designers specialise in the 'artificial world' of products and objects created by humans. Their knowledge stems from interaction with this artificial world; engaging in and reflecting on its activity, or by copying, reusing, or changing features of artifacts and learning through the process of creation. Cross (2001) refers to this as a 'designerly way of knowing' distinct from knowledge generation in science or the arts. Where scientists solve problems through analysis, designers solve problems through synthesis. As an example, he refers to Lawson's experiment (Lawson, 1979) who compares the problem-solving strategies of designers with those of scientists:

> The essential difference between these two strategies is that while the scientists focused their attention on discovering the rule, the architects were obsessed with

> achieving the desired result. The scientists adopted a generally problem-focused strategy and the architects a solution-focused strategy. Although it would be quite possible using the architect's approach to achieve the best solution without actually discovering the complete range of acceptable solutions, in fact most architects discovered something about the rule governing the allowed combination of blocks. In other words, they learn about the nature of the problem largely as a result of trying out solutions, whereas the scientists set out specifically to study the problem (in Cross, 2001, p.225).

Many authors highlight design as a 'third' area next to science and arts & humanities. Owen (1998) designates that we cannot delineate design as science or art as "it has its own purposes, values, measures and procedures" (p.10). For Schön (1983) design is not 'solving problems' in a linear sense, since that would mean problems are a given fact and already defined and all we need to do is find a suitable solution. More authors opposed the idea that design processes should follow a linear approach from problem definition to problem solution as the type of 'problems' designers try to address do not lend themselves to deductive or linear thinking. Bryan Lawson (1980) describes design as the interplay between problem and solution whilst the designer undertakes the activities of analysis, synthesis, and evaluation in an iterative process. Rather than trying to 'scientise' the practice of design, researchers in the field of design came to understand their unique ability in thinking and in doing and have since carved out a space in the professional world. Nigel Cross (1982) refers to this as 'Designerly ways of Knowing' which he unravels as designers tackle 'ill-defined' problems, their mode of problem-solving is 'solution-focused;' their mode of thinking is 'constructive;' they use 'codes' that translate abstract requirements into concrete objects.

Saikaly (2005) provides similar characteristics of a 'designerly mode of inquiry' in design research: (a) *designers deal with fuzzy research problems* where the research problem is not explicit upon the start of the process, but rather unfolds as the designer goes through different stages of field of interest, literature review, precedent, empirical work, more literature search, defining the problem space, defining the research questions. (b) *a cyclic design process* where each cycle might represent one design project or a component of a project. (c) *underlying adductive thinking* where incomplete information and observations are used to find the likeliest possible explanation. Decisions are driven by what might be rather than about presenting evidence of what works (inductive thinking) or what is true or false (deductive thinking) (Dorst and Cross, 2001; Kolko, 2010).

2.3.3 Design thinking

A few recent developments are impacting the way designers work: (a) the increasing complexity of design problems has led to the involvement of multiple agencies and a need to use co-design methods or participatory forms of design. This changes the role of the designer and the design practice in itself and shifts the focus from designing products to designing for a purpose (Sanders and Stappers, 2008) and (b) the physical or engineering part of design has moved to countries where most of the production takes place. This has separated the design practice from the physical practice or at least moved it further apart. Design firms had to rethink their ways of working from designing and producing products to selling design concepts. This has further implications for the design process which now relies more on 'creative exploration' and quality inputs from expert designers who can work without a brief or a defined problem space or context (Kees, 2009). However, as Sleeswijk Visser (2009) cautions that this development can lead to the exclusion of designers in the early phases of the design process. Even if the researchers have consulted the users in the pre-phase of the design process, this information might not be passed on and designers only receive an abstract brief without the user experiences that inform and inspire the designers. This reduces design practice to finding solutions to predetermined problems.

Design thinking emerged in the 2000s as a way of reselling "design light" to business leaders as a universal way of innovative problem-solving (Kimbell, 2011a). Most prominently advocated by IDEO's design organization their' inspire, ideate and implement' process is meant to keep designers focused on the people they are designing for to arrive at optimal solutions that meet their needs (Brown, 2008; Brown and Wyatt, 2010). What IDEO refers to as an HCD design process, originally human-centered design and has recently been reinterpreted to mean 'Hear - Create - Deliver'. The Hasso Plattner Institute of Design (commonly known as Stanford d.school) similarly promotes a 5-step process containing modes of thinking labeled 'Empathy - Defining - Ideation - Prototyping - Testing' which can be applied as non-linear steps. Another well-known example stems from UK's Design Council 4D model 'Discover - Define - Develop - Deliver'. UK's Design Council created a Double Diamond visualization to indicate two cycles of divergent and convergent thinking. In the first cycle, divergent thinking generates insights for problem discovery and convergent thinking narrows down what the designer team will focus on. In the second cycle, many ideas and potential solutions are drawn up during the divergent phase and narrowed down when creating viable solutions. The underlying principles of each of these frameworks can be summarised as empathy or gaining insights to imagine preferred situations, followed by a process of reframing the problem situation using a multi-disciplinary team to open the thinking space (diverging) and converging the potential solution stream. Early exploration of a selection of these ideas with field testing followed by further prototyping and refining leads to higher fidelity and ironing out any further issues. This process is iterative and starts with many ideas on the table, moving through the stream of potential solutions, rapidly testing them, and using the lessons learned to generate higher fidelity prototypes. A more visual approach through the development of prototypes or artifacts is believed to help multidisciplinary teams collaborate and the non-linearity of the 'design' approach leads to more innovative problem-solving (Kimbell, 2011a).

2.4 Participatory design

2.4.1 Research through Design

Design research and design practice are often conflated in design thinking. However, both are necessary elements in a design process. Frayling (1993) demarcated the relationships between research and design practice as *research into design, research for design,* and as *Research through Design*. *Research into design* refers to research on the practice of design, on how design works. Nigel Cross refers to this as design anthropology, praxiology, or methodology research which indicates its reflexive practice in describing the design process and evaluating how the design process expired. *Research for design* also explores the design practice or design research, but from a different angle. Here the aim is to improve the practice of design, rather than documenting it or trying to untangle 'what it is'. Often in research for design new methodologies or approaches are proposed. Usability studies and, user requirements gathering, or user research often used within a user-centered design approach are frequently referred to as research for design (Stappers and Giaccardi, 2017). *Research through Design* uses the methods and practices of design discipline and applies this to conducting research. It aims to generate new knowledge using design inquiry rather than using scientific methods, for example through reflective practice, reframing the problem situation, and using an iterative approach to creating and/or critiquing artifacts used to explore solutions (Zimmerman and Forlizzi, 2014).

Research through Design has three distinct features that sets it apart from scientific modes of inquiry (Zimmerman, Stolterman and Forlizzi, 2010). First, its focus on the use of designerly approaches helps to tackle and make sense of otherwise messy situations where problem - analysis - solution processes might not be appropriate. Where scientists solve problems through analysis, designers tend to solve problems through synthesis (Zimmerman et al., 2010). Rather than finding the 'right way' of doing things, designers not only design but also test many solutions and only then select the most appropriate ones given the situation. Second, Research through Design approach tend to focus on the future, on imagining 'what could be' rather than focusing on the past or present as is common in the natural and social sciences. And third, due to its nature of using design practice and artefacts to explore future not-yet existing situations or solutions it adds an additional layer of reflexivity on *how* we design by constantly framing and reframing the problem and designing artefacts that serve as tools of investigating potential solutions in a more structured way compared to designing prototyping through applied methods of enquiry (e.g. Tinkering until the proposed solution becomes appropriate in a given context or for a specified audience). Design choices are intentionally made and documented and the ethics of what design are considered (Zimmerman et al., 2010).

Research through Design can be distinguished into three different design practices classified as the Lab, the Field and the Showroom (Koskinen *et al*., 2011). The Lab refers to the use of artefacts as physical hypotheses which are tested under controlled laboratory conditions. Varying the prototypes to generating quantiative data the designers are able to build theories on design. Second, the Field refers to the implementation of participatory design, borrowing its research practices from social science and anthropology to seek an understanding how users interact with a artefact in real-life contexts. It is also used to learn about process of participatory design to advance the method. Last, the Showroom refers to the practice of speculative or critical design to seek change or challenge the status quo.

2.4.2 Participatory Design

A movement emerged in the 1960s in Scandinavia focusing on user participation in the development of systems involving human work. 'New' technologies such as personal computers were designed to increase productivity yet were not taking usability issues into account. Participatory design brought together scientists, designers and behavioural

psychologists to prototype new modes of interactions by envisioning a future state rather than advancing (e.g. Tweaking) the technologies in itself.
Whilst initially the prototypes were meant to result in a commercial product, researchers were also keen to develop a new design methodology using their built artifacts as research tools rather than products (Zimmerman and Forlizzi, 2014). This is where participatory design originated and laid the foundations of involving people in the co-design of technologies. It has since evolved as a research discipline on its own in addition to the application of its principles and practices in many other fields. Participatory design aims to "understand how collaborative design processes can enable the participation of those who will, in the future, be affected by their results" (Simonsen and Robertson, 2012, p.2).

With the application of participatory design in many different fields it has grown to become a 'proliferating family of design practices' (Brandt, Binder and Sanders, 2012, p.145) and encompasses an extensive range of tools and techniques to support participants in telling, making and enacting aspects of future design (Brandt et al., 2012). Different stages in the design process utilise different tools. The use of visual materials allows participants to share their experiences in a manner that is intuitive. The use of games can facilitate a common language between stakeholder groups with different ways of knowing. The use of ethnography is borrowed from the field of anthropology to understand the needs of users.

The ability to 'make' physical artefacts provide non-designers with a way to express their needs and describe their views for the future. It allows designers and non-designers to work collaboratively. Cultural probes, for example, the use of immersion workbooks, diaries, send-a-camera home, can be used by participants to reflect on their experiences and share their thoughts with designers (Gaver, Dunne and Pacenti, 1999). Prototyping allows designers to show their views on 'what could be' in a physical form (through mock-ups and low-fidelity versions of a 'thing') which helps them evaluate in part or whole the attributes of a prototype. Generative activities prepare participants for creative work, for example the 'a day in the life of' exercise. Commercially available generative toolkits, for example LEGO Serious Play (c.f. Mccusker, 2020) or Design Methods cardsets (maketools.com) offer businesses and classrooms the opportunity to use participatory design in a formal setting. The process of *enacting* allows participants and designers to develop and explore ideas using role-play, improvisational theatre or scenario-based techniques.

2.4.3 Co-design

(Sanders and Stappers, 2008) make a distinction between co-design and co-creation. Co-design is a collective activity carried out throughout the entire design process, whereas co-creation describes any activity that is experienced or performed jointly by a group of people with the intention to create an outcome that is not known in advance. Co-design, therefore, is a form of co-creation. Co-creation can be seen as a form of 'open innovation' where end-user involvement is encouraged in one or more stages of the design or research process (van Stiphout, 2011; Frow *et al*., 2015). A similar distinction between co-design and co-creation can also be made for agriculture. Co-design involves heterogeneous stakeholders in a process of collaboratively seeking solutions to common problems, where collaboration is based on common understanding of a problem (Berthet, Hickey and Klerkx, 2018), either by involving stakeholders in co-design processes or through co-production where stakeholders are involved in implementing proposed solutions, the latter of which could be referred to as co-creation. However, co-creation could also entail participatory forms of consultation which would not reach similar levels of participation as co-design would. For example, the general involvement of stakeholders in conducting needs assessments and setting the parameters for a model versus the involvement of stakeholders as active participants in the process through the production, assessment or evaluation of knowledge serving (at least in part) their own interests.

Lacombe, Couix and Hazard (2018)(2018) distinguishes between five different approaches of co-design: *de novo-design* where researchers design prototypes which consist of ideotypes, conceptual maps or computerised models of farming systems with the help of farmers (Cobb and Thompson, 2012; Oliver *et al*., 2012). In c*ase-study design* researchers invite farmers and other stakeholders to assess scenarios or modelled changes in a farming system (Bousquet *et al*., 2007; Barnaud, Bousquet and Trebuil, 2008). In *niche innovation design* researchers use 'reflexive interactive design' (Bos *et al*., 2009) to facilitate system innovation. Stakeholders are taken through a design process to generate innovative ideas and adjustments to the farming system. In *co-innovation* farmers participate in innovation networks or training centers (Tittonell *et al*., 2012) or farmer networks (Botha *et al*., 2017) to identify innovative solutions to shared problems. Last, *activity-centered design* aims to solve structural problems on a local level through mediating a learning process based around individuals doing the same activities (Triomphe *et al*., 2008; Vänninen, Pereira-Querol and Engeström, 2015). Social learning or peer-to-peer learning facilitates knowledge sharing activities between stakeholders and takes learning beyond the individual to networks and systems (Kristjanson and Harvey, 2014). Usually, the intention of social learning is to create some sort of social impact or behavioral change (Reed *et al*., 2010).

2.5 Summary

There are well-recognised barriers to participatory research in terms of its effectiveness, efficiency and sustainability. Citizen science and advances in participatory modelling using digital technologies and games may offer new opportunities to overcome these barriers, yet also highlight unresolved issues. Citizen science has brought attention to more diverse configurations of participation that can involve more differentiated roles of participants, both more active and more passive forms of participation, and with a stronger emphasis on the design of the experience of participants. Similarly, participatory modelling proved to be a powerful tool for collaborative learning and as a method of identifying solutions to shared problems. Yet as Voinov *et al*. (2016) indicates most of the time stakeholders are involved in data collection and project evaluation, rather than in goal setting and model formulation. Much creativity can be unleashed when agricultural scientists get involved in the wider community of scientists that are engaged in participatory research and co-design and work with designers.

Design refers to both the methodological underpinnings and the practice of doing design. As for the first meaning, it can be seen as a way of enquiry distinct from scientific enquiry or the arts. Design practice is the act of design, the ability of designers to solve problems. Here, three approaches are highlighted: participatory design to explore how to involve users in collaborative forms of research, and Research through Design which uses the methods and practices of design discipline and applies this to conducting research. Co-design is increasing in popularity for the design of participatory agricultural research and is highlighted here in terms of its position in the wider field of design research.

Chapter 3

Research approach

3.1 Introduction

I have been fortunate to be able work with farmers in different environments in countries in Asia (Vietnam, India) and Africa. From 2012 to 2020 I have worked for Bioversity International in a position that required frequent travel to countries in East and Southern Africa (Ethiopia, Kenya, Tanzania, Uganda, Malawi, Mozambique). This has given me a better perspective of the complexity of farming systems and how they are connected within global networks. And unfortunately, also made me aware of the occasionally 'extractive' nature of participatory research in agriculture. In both my work and my studies, I have aimed to understand social and technical change and their interdependence. This has given me more insights in the social dimensions of environmental degradation and poverty and the fuzziness in technology transfer. Agricultural researchers today still take the lead in setting the criteria for conducting research and create solutions in 'laboratories'. The participation usually comes afterwards when they are testing the technology or solution and need input from the end-users (farmers). I am convinced that we need interdisciplinarity between scientific disciplines to be able to work towards sustainable agricultural production. This has inspired me to think of a more structural investigation into participatory research methods that are less extractive and engage farmers in a more democratic way. For example, by recognising farmers as co-authors, setting up social contracts so that the benefits of participation are clear from the start and above all facilitating better research processes where farmers can select their own research priorities and where farmers and researchers will share the benefits from the activities.

Bioversity International developed an alternative approach to participatory research for agricultural crop evaluations using the principles of citizen science and crowdsourcing. As this was quite innovative for our field, many other organisations were interested in giving the approach a try as long as it could be adopted for their specific research needs. After a few years of experimentation, we found that the approach was successful in its ability to involve large numbers of farmers into on-farm experimentation and brought valuable and usable data. However, it still lacked in its abilities to involve farmers in setting the goals for experimentation (this was mostly done by researchers beforehand) or in "identifying needs and setting targets, developing ideas for new technologies, selecting which technologies to evaluate, and which questions to ask in evaluation". In short, how to involve farmers in designing the research approach. Secondly, much is unknown on what drives participation in terms of motivation and engagement and whether this can be "differentiated by gender, age and other social and economic factors, and to establish what design strategies might best address these factors in this context.", or how to design for engagement.

As part of a consultancy for the McKnight Foundation we offered training sessions to research groups in southern Africa teaching them to use crowdsourcing tools and methods of up scaling technology testing. Farmer engagement is high within the Collaborative Crop Research Program and they have set up well-functioning Farmers Research Networks where farmers set the research priorities together with local researchers. They bring together farmers, NGO's, researchers and the private sector and have managed to create a bottom-up structure for experimentation and co-creation.

Through these experiences and the different needs other organisations expressed in the requirements for the tricot approach, I became interested in bringing concepts of design thinking and more inclusive and innovative approaches into agricultural research methodology. This thesis has been an exploration of designerly approaches and how they can be applied in participatory agricultural research in low income countries, yet perhaps more importantly the dissertation describes the exploration of designerly approaches as a *way* of doing research, relying on the concept of Research through Design. To generate insights on how we can involve users into the design of agricultural research.

3.2 Research approach

This research adopts a Research through Design approach, where designerly ways of *conducting* research are used (figure 2). Research through Design plays a formative role in the generation of knowledge and uses design principles or 'designerly ways of knowing as part of doing research to gain an understanding of complex situations (Cross, 2001). As Wensveen (2018), an early practitioner of the rtd approach describes "the design process becomes the research process and knowledge is generated and communicated through the designed artefact" (p.13). Carrying out design activities allows the researcher to explore what 'could be' by presenting users with hypothetical future scenarios and exploring the outcomes and consequences The design activity is used as a research method. For a comprehensive overview of the origins of the rtd approach, I refer to Stappers & Giaccardi (2017).

Here, I emphasise the use of the concept of 'artefacts' rather than prototypes or products. The artefact is used as a tool for knowledge generation or to facilitate some form of interaction. I build and use prototypes as a research tool, without having the intention of creating a product. Through evaluation of structurally varied prototypes, interactions become more visual and make the combination of factors leading to the acceptance of a prototype more visible (Sleeswijk Visser, 2009).

> "The designing act of creating prototypes is in itself a potential generator of knowledge (if only its insights do not disappear into the prototype but are fed back into the disciplinary and cross-disciplinary platforms that can fit these insights into the growth of theory)." (Stappers, 2007).

I use Research through Design to carry out two design experiments under field conditions to answer my two overarching research questions. First, I use Research through Design to build artefacts that explore how form design could improve the intrinsic motivation of participation in agricultural research. And second, I use Research through Design to reflect on the application of designerly approaches: through building artefacts and exploring its use in our specific context I consider *how* we can involve users in the design process in the early stages of developing a research project. For example, using design artefacts as a purposeful action to explore feedforward, e.g. Creating prototypes to explore how participants in agricultural research would like to receive feedback on the results of their tricot trials (see chapter 8). The prototypes that the design team developed to conduct the research are the result of an iterative process of design and field-testing. For the iterations on the data collection forms, the team took the original forms and intentionally changed variables such as input types, typography and colour, instructions and incentives. These were compiled into different versions and taken to the field, observing participants interactions with the form. Or by purposefully designing training activities as artefacts to explore and measure if different activities lead to changes in participants' perceived levels of self-efficacy or understanding (chapter 9). Design-driven approaches focus on the experiences or the affordances of the designs, rather than evaluating and improving an artefact. The research is design-led in the sense that I created interventions and studied the development process as well as the effects of these interventions. Design-led refers to a research methodology which used design practice or tools to explore what can be learned through practitioner action (Sanders and Stappers, 2008). The research activities were not designed to offer solutions to existing problems, rather used as a tool to study the interactions and impacts the design choices had on the chosen interventions.

I borrow from (participatory) action research to carry out iterative research by planning, doing, observing in collaboration with end users and reflecting on the process. By taking the artefacts to the field and working together with participants in tricot research, I can learn more about their user experiences and how we might improve the design of the participatory process in terms of its communication, data collection and feedback mechanisms. Action research aims to empower the end-users to become more aware of the role they play in the process and how they can contribute to the process. In my case, I seek understanding on the role that end-users (farmer participants in agricultural research) can play in the early stages of the research process, where goal-setting and design of the research takes place. Both action research and Research through Design are cyclic in nature and alternate between action and reflection in iterative rounds of research. To me what sets Research through Design apart from action research is the deliberate design of varied prototypes to generate knowledge through a process of building and evaluating. Whilst experiential and social learning could be an important aspect of the Research through Design process, particularly when participatory forms of co-design are applied, it is not its main purpose.

3.3 Design process

I adopt a standard design process guided by the Double Diamond framework (Design Council UK, 2005). The framework could be seen as restrictive, as mentioned earlier in the literature review, by creating an illusion that a design process can be carried out as a step-by-step process. Furthermore, the limited explanation of what each step in the process entails could lead to a shallow interpretation of how to "do" design. Here, I take a pragmatic stance and consider my inexperience with design practice. Dan Nessler's "double diamond" revamped (Nessler, 2016) provided a useful perspective of an otherwise abstract representation of a design process and sufficient scaffolding to get started with my journey. Using the framework offered useful guidance and helped me to deep dive and explore methodologies of design synthesis, ideation, and iteration.

Whilst the graphic (figure 2) suggests that the design process can be viewed as structured phases of diverging and converging or of synthesis and analysis, this does not reflect my research process which consisted of a non-linear process with many iterations and even more diversions or side paths worth further exploration.

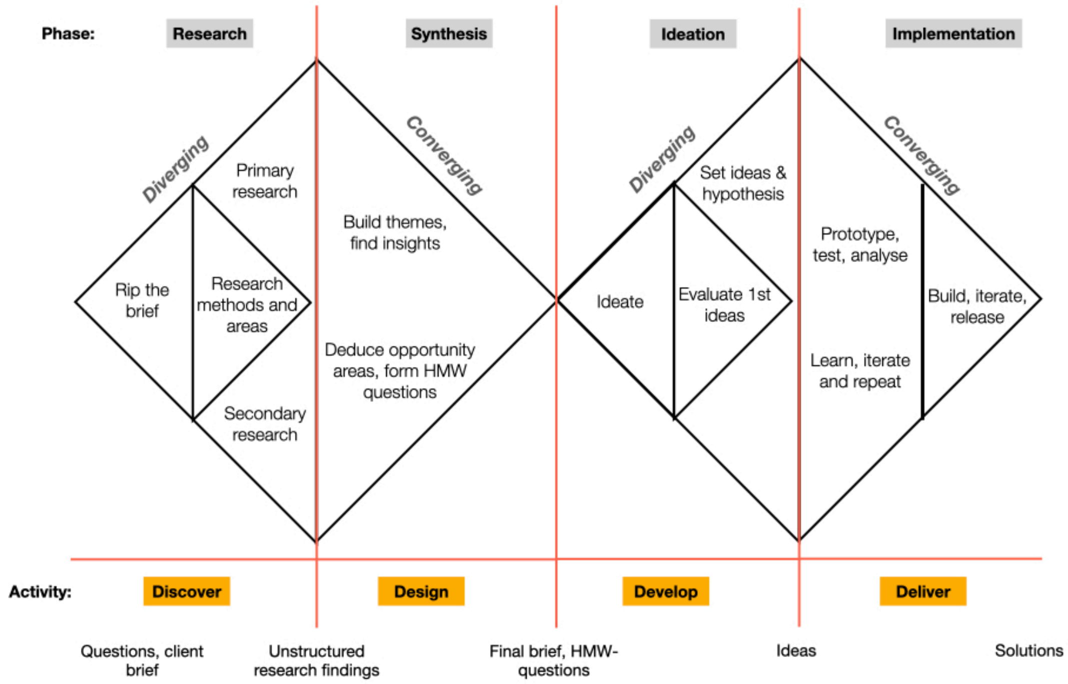


Figure 2: The double diamond design framework (Nessler, 2016)

This research focuses on designing in fuzzy front end of the design cycle e.g. The early stages of designing a research process. This part of the design process is where decisions are made on *what* and *how* to design. The fuzzy front end brings together primary and secondary data from a variety of sources. The concept refers to the pre-design phase where the problem space is not yet clearly defined and deliverables can still take any form or shape (Sleeswijk-Visser, 2009; Sanders and Stappers, 2008). In this phase designers gain an understanding of the users, the user context and explore the technical and theoretical opportunities of the design solutions (Sanders and Stappers, 2009). March (1991:71) describes two ways to approach adaptive processes; exploring new possibilities and exploiting old certainties. Exploratory innovation refers to a process of seeking new knowledge or design processes where objectives are not clearly defined. Exploitative or incremental design processes, sometimes also referred to as rule-based design aims to improve existing products or services to achieve predetermined goals (Berthet *et al*., 2016). Existing knowledge is 'exploited' and expanded upon without looking at the system (e.g. The drivers and hurdles to fulfilling its goals).

3.4 Design methodologies

Design practice refers to the act of 'doing design' often through a process of *making* where designers use prototypes, personas, storyboards, scenarios, probing packages, or generative toolkits. Design researchers and their co-designers create interpretations of ambiguous questions and answer them or participants are handed artefacts to interact with and discuss their use and implications, often in iterative cycles (Koskinen *et al*., 2011; Sanders and Stappers, 2014). Design methods are not used rigidly but transformed and reconstructed creatively. Moreover, in design research, these methods are used to inform and construct meaning, rather than to develop a product or a service (as a means rather than an end) (Sanders and Stappers, 2014).

Several design methodologies form the basis of the empirical work of this thesis. These are iterative design, design synthesis, ideation and the use of generative tools. Each of these methodologies (or approaches) are associated with different methods, tools and techniques. Iterative design was used for building the prototypes and designing the training activities as described in chapters 8 and 9 respectively. Design synthesis used different ways of modelling data (activity chain analysis, service blueprints, user journey mapping) and the framing and reframing of the problem space. Ideation used precedent studies and tools for idea generation (sketching every idea, war room, brainstorming and formulating how-might-we questions). Generative tools used were the cultural probe, and generative techniques to design training activities). Last, design research studied a case study and used context analysis, user interviews, observations and fieldnotes and analysis of secondary data.

3.4.1 Iterative design

Iterative design refers to a process of building and learning in order to improve or rethink design ideas. In its simplest form it is a process of repeated design and testing intended to refine designs. Iterative design is one of the cornerstones of design processes as it collects and processes information on a design problem, revising and improving it in a cyclic manner. (Zimmerman, 2003:176) refers to this process as "Test; analyze; refine. And repeat.". Every cycle provides valuable data on what works under a specific set of circumstances leading to adjustments of prototypes. This is what iterations are; subsequent versions of your designs (Zimmerman, 2003)

Design phases sometimes run parallel and emphasis lies on the loop of action and reflection to generate possible solutions. This entails iterations that do not necessarily lead to a higher fidelity prototype or a refinement of an artifact, as there might be dead ends causing a complete restart of the process, or partial failure with a change of direction.
It is not a finite process where a set number of iterative rounds of *making* will lead to a design ("I do 3 rounds of iterations and then i'll have a perfect design") or even a structured process where each iteration will lead to a improved design. In a way iterations could be seen as setting yourself up for failure in order to learn from the process.

I use iterative design processes in several phases in my research; for exploring the problem space, to build prototypes for data collection, feedback delivery and knowledge sharing activities (chapter 8) and to design training activities (chapter 9). Prototypes are used as an exploration of artifacts without offering a solution or which only partly work, in order to generate greater understanding (Koskinen *et al*., 2011; Wensveen and Matthews, 2015).

As is common in Research through Design, prototypes constitute artifacts that enable the interaction that is studied. It is not designed to be a low fidelity version of an end product. Prototyping should not be about releasing half-products and then evaluating them with user groups, but to design an artifact that communicates design options to the users in such a way that we can get closer to a solution or provide us an interface to facilitate interactions. For example, do we know whether the end-users in our study are receptive to western-designed pictograms? Showing them paper prototypes with pictograms, could provide us with insights that could answer this question. Yet if we show them a mobile phone application that is nearly finished and let them run with it, all we do is evaluate if the mobile application works as intended. We wouldn't be able to easily explore alternatives (who would build 3 apps and test which one would work best?) And therefore, we wouldn't know if there is anything that might work better.

3.4.2 Design synthesis

Synthesis is an indispensible feature of any design process where after an initial flurry of doing design research, conducting interviews and collecting secondary data there is a need to make sense of it all and digest the information. Whilst often considered an intuitive and unstructured process, there is logic to it. Kolko (2011) explains synthesis as an abductive sense making process. Design synthesis uses abductive reasoning where incomplete information and observations are used to find the likeliest possible explanation. Decisions are driven of what might be rather than about presenting evidence of what works (inductive thinking) or what is true or false (deductive thinking) (Dorst and Cross, 2001; Kolko, 2010).

Synthesis refers to the act of modelling data, pruning or filtering information or organising data in a certain way to produce information and knowledge in order to create high level themes or patterns to help along the design process (Kolko, 2010). For example, synthesis occurs when designers digest the information that is available to them and 'get it out of their heads and onto paper', or when design teams start creating 'the wall of post-its'. Kolko (2011) argues that it is far from a arbitrary process and that the methods and principles of design synthesis are transferrable and repeatable. As Kolko describes: "Synthesis is a sensemaking process that helps the designer move from data to information, and from information to knowledge" (p.40). Design synthesis shapes the plurality of data into a condensed form by modelling the data in a more abstract form. This more abstract representation might help to create the insights needed for the ideation process. The outcome of the process of design synthesis is a set of criteria for that will lead to the design of solutions. Kolko provides an extensive overview of the inner workings of design synthesis in the first part of the book on 'Exposing the magic of design' (2011). In addition, he provides a list of methods to structure the synthesis process. In this thesis I tried to tackle design synthesis using several of his methods, especially methods intended to make meaning out of the data. For example, I tried my hand at modelling the data brought forward in chapter 5 into activity profiles (see 6.3.2) and by visualising user journeys or experience maps (see 6.3.4). I took inspiration from his methods on reframing to demarcate the problem space (figure 3). I describe how I structured the process of design synthesis is this research in the introduction of chapter 6.

Figure 3: Contextual factors put on a 'research wall' (photo: Jonathan Skjøtt, 2018)

3.4.3 Ideation

Ideation is the process of generating and developing ideas (Jonson, 2005). It is the conceptual phase in the design process where ideas are discussed and explored usually using some form of visual representation. Traditional methods of ideation are sketching, creating collages or storyboards or performing role-play (Keller, 2008). Ideation is the process that follows after the synthesis process effectively narrows down the design requirements, and opens up the design space again in a process of diverging. Ideation entails a process of compiling ideas, evaluating ideas and sketches and start to compile the first design drafts or prototypes (Nessler, 2016). Suggestions for the ideation process range from 'sketching every possible idea' and exploring the design space in 'breadth' (Daly *et al*., 2016). To avoid sticking to the more obvious design solutions it can help to break open the design space using precedent. Precedent can be defined as reference material of existing 'product' forms that could help explore possible design solutions (Pasman, 2003). The design knowledge derived from a precedent study offers a frame of reference for the designer to draw inspiration from, rather than attempting to fit existing solutions to a new situation. Pasman (2003) refers to this transfer of design knowledge as a process of active adaptation of design knowledge from precedent to use in the design process and to adapt it to new circumstances. Evaluating precedent in a structured manner offers the opportunity to assess an already worked-through solution and distill lessons learned.

Ideation occured at several points during my Research through Design process; after concluding the design synthesis phase when the design team conducted a precedent study and brainstormed and evaluated the ideas for the first design experiment as described in chapter 7. Shorter bursts of ideation occured after we brought back many ideas generated during field testing and had to rework these into completely new or redesigned prototypes. As such ideation is part of the iterative process and almost never occurs as a standalone activity, it is interwoven in the non-linear design process where designers sometimes go back and forward between the different steps.

3.4.4 Design research

I look at a real-life implementation of a citizen science-inspired participatory crop improvement scheme that serves as a case study for the application of citizen science in participatory agricultural research. The *tricot* approach is developed by Bioversity International, a research organisation focusing on promoting agricultural biodiversity and sustainable food systems. The tricot approach serves as an interesting example of an approach that, as it is still under development, holds the opportunity of highlighting several issues in the traditional implementation of participatory agricultural research as well as the ability to look at its novel ways of involving users into its research processes. Whilst it has been very successful in increasing the number of participants in its research processes and its ability to generate big data, the designers of the approach indicated that it still lacks accountability towards the end-user and therefore might lack engagement from its users (CCRP, 2016). As the tricot approach is intended and modelled after citizen science principles, I used this opportunity to explore ways of using the tricot approach truer to its citizen science intentions and attempted to increase its public accountability and mutual learning and knowledge making/sharing.

The tricot research has been piloted around the world with different purposes, here I chose to focus on its implementation in East Africa. There were two reasons for this. First, I have been involved in the development of the tricot approach as part of the work for Bioversity International whilst based in their office in Nairobi, Kenya. See for example (van Etten *et al.*, 2008, 2016, 2019; Steinke *et al.*, 2019, 2020; Ortiz-Crespo *et al.*, 2020). And secondly, tricot trials in Tanzania and Kenya were used as pilot studies for further development of the approach and had trials ongoing at the time of commencing this research.

3.3.5 Design reflection

David Schön (1983) defines the concept of 'reflective practice' as a practice of design professionals to become aware of their tacit knowledge and learn from experience. He distinguished between three types of reflective practices: first, *reflection-in-action*; reflections or observations that are noticed during the implementation of the design activities or on behaviour as it happens. As designers become aware they may choose to act on this, which in turn will influence the further doing (Reymen, 2003). Second, *reflection-on-action* usually occurs after an event takes place. It is when designers look back on their activities and reflect on what they have done and what understanding this might bring. Team debriefings or compiling field notes are examples of reflection-on-action. Reflection-on-action technically could also take place during an event, when a designer decides to take a break and reflect on the activity. Lastly, Schön refers to *knowing-in-action* which refers to the tacit knowledge that design professionals carry with them into the design process. It's the *knowing-in-action* that sets aside design professionals from other professionals as this feeds their capacity to deal with the unexpected and ability to improvise (Schön, 1983, p. 60).

Reflection-on-action formed an important aspect of the iterative design process as we reflected on the events after they occured. For example, after developing (partial) ideas during the ideation process, our team reconvened to discuss the appropriateness of the designs. Similarly after each field testing day, the team reconvened to debrief on the process, and each separate activity and how to improve the activities for the next round of field testing. Here the reflection focused on past events with the aim to prepare and determine future activities.

The reflective practice is also an important facet of my Research through Design approach. I ascribe to Reymen's explanation of reflective practice in a design process which sees reflection as a "introspective contemplation on the designer's perception of the design situation and on the remembered design activities" (Reymen & Hammer, 2002:p.887). I reflect on my own design process and how or what I can learn from applying designerly approaches in my research for each of the steps in the design process of this thesis. This is different from the social science practice of reflection, where one would consider their personal preconceptions, biases and viewpoints and how they might have impacted the research results. For me, adopting a structured form of reflection was particularly useful to answer the meta-level research question which overarches this thesis: What is the value of adopting designerly methods when configuring participatory approaches for agricultural research? As it was the first time I led a design process from start to finish, reflection also enabled me to gain more insights on my design practice and obtain/acquire deeper learning. I followed her systematic approach to reflection-on-action in preparation, image forming and conclusion drawing.

3.5 Summary

I experiment with the use of existing designerly approaches and methodologies for designing participatory research. Using empirical research generated through my design experiments I provide practical insights in how to design for motivation in participatory agricultural research. I do this using a more or less standard design process of design research, synthesis, ideation and iterative cycles of prototyping using a variety of different methods and tools associated with each of these methodologies. Furthermore, I reflect on the use of designerly approaches for agricultural research and in particular for our user context consisting of smallholder farmers by studying a real-life example of participatory agricultural research in East Africa.

Chapter 4

Tricot approach

4.1 Introduction

I use a case study in this design process studying a existing citizen-science inspired participatory agricultural research approach. In this chapter I present the approach and the user context of this study.

4.2 What is “try-cot”?

Bioversity's work in participatory agricultural research has led to the development of the triadic comparisons of technologies approach for crop variety selection. The approach is the culmination of several years of experimenting with designing citizen-science-inspired participatory forms of agricultural research. The first designs of the approach were named crowdsourcing crop improvement, referring to the use of the wisdom-of-the-crowd principles to generate data on varietal preferences. As is common in academia and science, early iterations of the approach were presented to solicit inputs from peers. The terminology of crowdsourcing presented a negative connotation in terms of outsourcing tasks to farmers to generate big data. This was not the intention of the scientists developing the approach so a more neutral term was needed to describe the research process. The approach aims to involve many farmers in a research process as citizen scientists, offering clear benefits for both its participants and the researchers initiating the research. Triadic comparisons of technologies (tricot, pronounced “try-cot”) refer to the experimental design of the approach where individual participants compare randomised blocks of three technologies. In this citizen-science-inspired approach, a large number of smallholder farmers individually evaluate a different combination of three crop varieties or other technologies on their farms. Feedback on these technologies is pooled and the results are shared back with participants on paper and through group discussions. A major benefit of the tricot approach is that less on-site supervision is needed from trained professionals throughout the process. This contributes to the cost-effectiveness and scalability of the approach. Tricot introduces new varieties or inputs or practices to participants giving them the opportunity to experience a selection of the varieties first hand. The approach empowers farmers to identify the most suitable technologies for the specific conditions of their own farm. Tricot can be used to evaluate a wide range of farm technologies. To this date, most of the experience has focused on crop varietal change.

4.3 How does tricot work?

Figure 4: Overview of the different steps in the tricot user journey

Participants are asked to complete a mini-trial by evaluating three varieties from a range of varieties that researchers want to include in the (overall) research trial. By combining the results of the mini-trials researchers are able to piece together the preferences in terms of performance of all varieties included in the research trial. Figure 4 provides an overview of the different steps it takes participants to complete a tricot research trial.

Participants receive a trial package containing different combinations of the three varieties which partially overlap with other users. They also receive a instruction leaflet and a paper data collection form. They are asked to plant the varieties in rows next to each other to make it easier to compare and rank the varieties for best and worst performance. A simplified data collection format (see example in figure 5) containing a forced choice between three technology options facilitates digital data collection. Participants are presented with the easy task to rank each variety for a predetermined set of crop characteristics at set times during the growing season. Local facilitators collect these observations and aggregate the data before they send it to a central database for analysis. The analysed data consists of a report and individual information sheets that are brought back to the participants during workshops planned at the end of each research cycle.

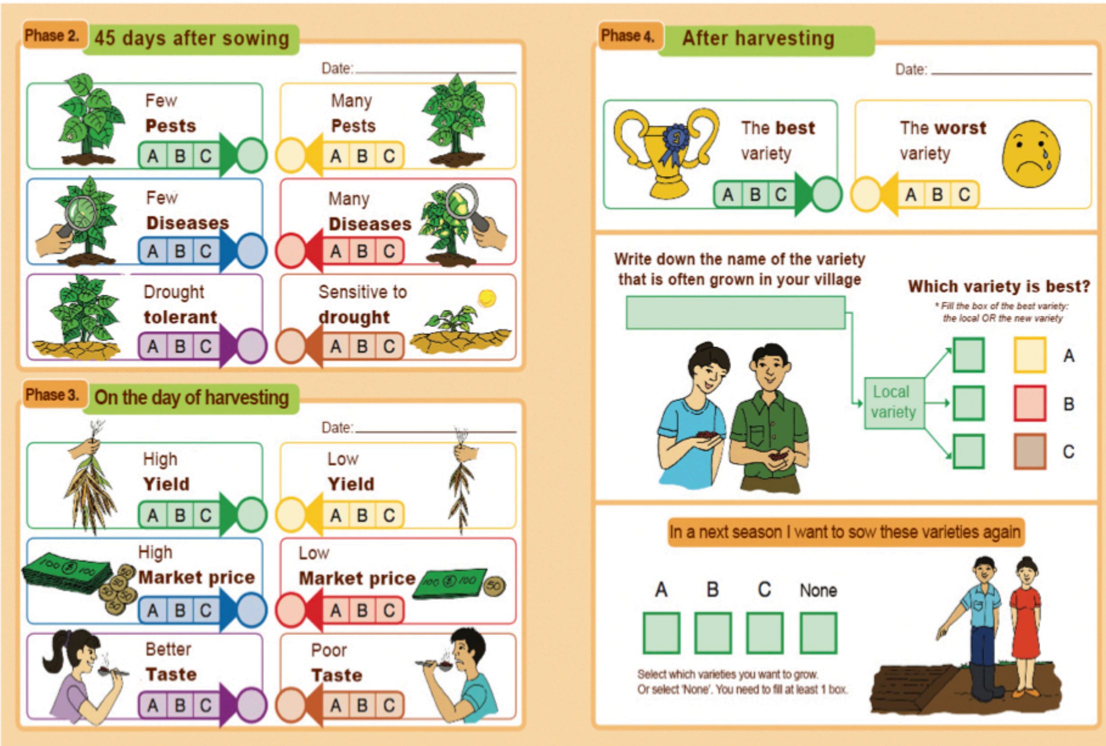


Figure 5: Data collection format for tricot trials (Bioversity International, 2015)

The approach doesn't require researchers to train participants in making scientifically valid measurements, doesn't require measuring devices and also eliminates the need for calibration of the data across data points

4.4 Tricot data collection and analysis design

The main aim of the designers of the tricot approach was to develop an approach that allows the upscaling of participatory on-farm testing of crop varieties. Van Etten *et al*. (2017:2) explains its purpose:

> Rapid climatic and socio-economic changes challenge current agricultural R&D capacity. The necessary quantum leap in knowledge generation should build on the innovation capacity of farmers themselves. A novel citizen science methodology, triadic comparisons of technologies or tricot, was implemented in pilot studies in India, East Africa, and Central America. The methodology involves distributing a pool of agricultural technologies in different combinations of three to individual farmers who observe these technologies under farm conditions and compare their performance. Since the combinations of three technologies overlap, statistical methods can piece together the overall performance ranking of the complete pool of technologies. The tricot approach affords wide scaling, as the distribution of trial packages and instruction sessions is relatively easy to execute, farmers do not need to be organised in collaborative groups, and feedback is easy to collect, even by phone. The tricot approach provides interpretable, meaningful results and was widely accepted by farmers.

The approach has undergone extensive field-testing from 2013 to 2016. Since then other institutions have adopted the approach and Bioversity has developed a online support platform which guides the researcher-user through all the elements of setting up a research trial and generates tools for digital data collection and aggregation and takes care of the data analysis (see https://climmob.net).

4.4.1 Experimental design

Tricot uses an incomplete block design for the dissemination of the varieties. If researchers want to test a pool of fifteen varieties of a specific crop, each participant will receive a randomised combination of three of these varieties. This makes it easier to observe differences in performance between three varieties then having to individually rank fifteen varieties. Trial dimensions are determined by the number of treatments multiplied by the number of different environments to be included in the trial. Testing varieties under different management practices will likely result in different performance of these varieties. Each of these so-called different treatments need to be sufficiently represented. Similarly, trial implementation across different environments might affect trial performance and therefore increase the number of individual trials (or blocks) needed to provide meaningful results.

An online platform is used to generate a randomisation that ensures that all varieties appear in equal frequency throughout the trial and is sequential to ensure that distribution of varieties is balanced in different locations. By partially overlapping the data from each individual mini-trial the data can be analysised to rank the relative performance of all varieties. The outcome of the trial is a performance ranking of all varieties included in the trial relative to the other varieties. See figure 6.

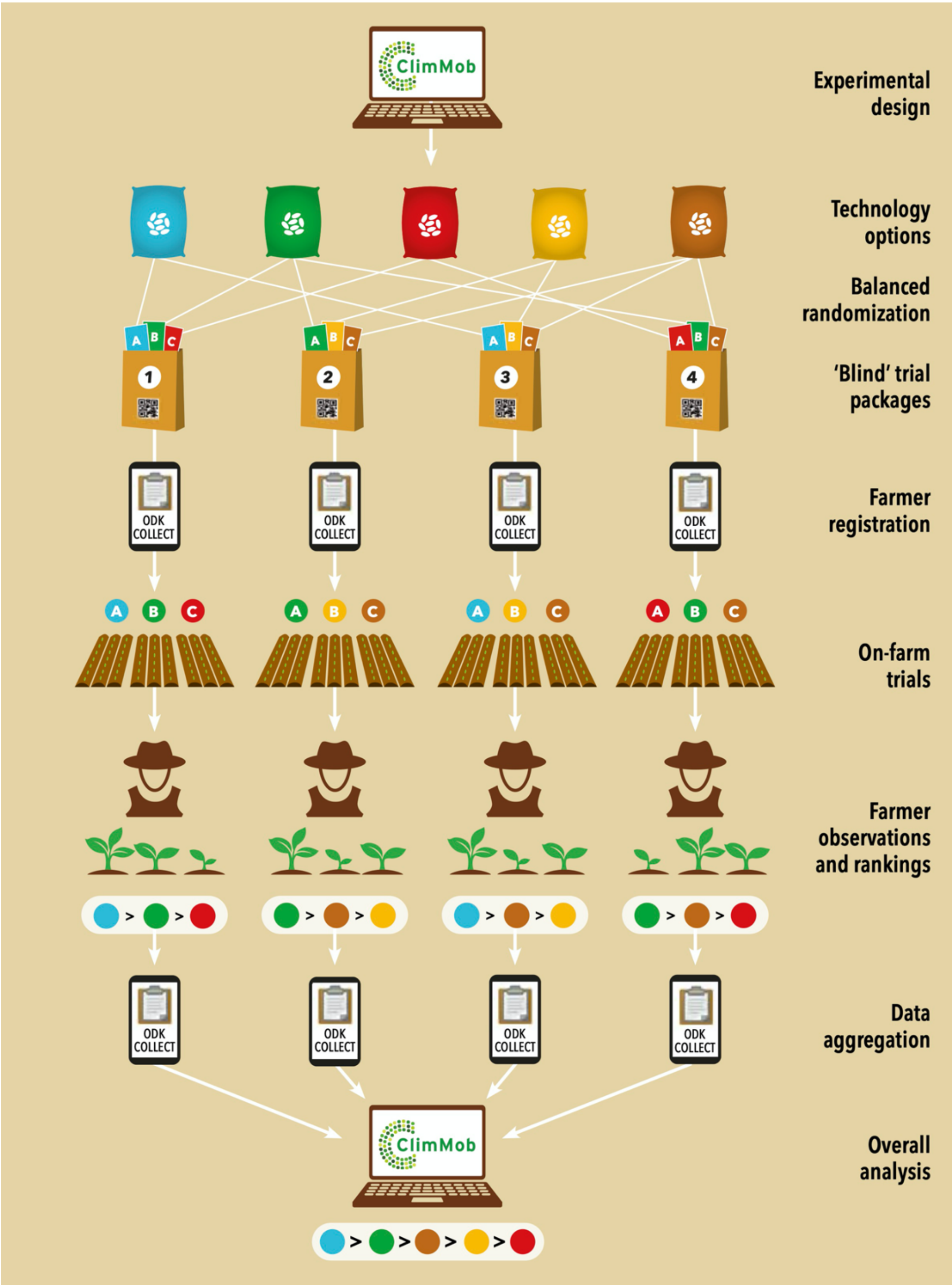


Figure 6: Experimental design of tricot trials (van Etten et al., 2020a)

Combining tricot data with existing data sets on farming systems, rainfall patterns, or agro-ecological zones can generate a rich picture on which varieties are considered to be more suitable for specific social or environmental conditions and further disaggregated it can represent preferences by for example, socio-economic status or gender which can be useful information to accompany the dissemination of each variety.

4.4.2 Research process

Tricot trials are initiated by researchers who want to test a range of different technologies in a participatory research trial. These technologies can be crops or varieties, fertiliser types or irrigation technologies. Designing the trial involves making decisions on the scale of implementation, selecting locations for testing, and determine the number of participants to be included in the trial. The online platform Climmob.net asks its users to specify the technology options and number of participants and set criteria for evaluation. This information is then used to create randomised lists of experimental blocks. The number of options (or blocks) equals the number of participants included in the trial. Each trial package has a unique number (or QR code) assigned to it which serves as a point of reference for the rest of the process. Researchers then usually hand over the project together with testing materials to an implementing organisation. Testing materials can be physical items, for example seeds of different varieties, or abstract in the form of recommendations for fertiliser inputs. The implementing organisation is responsible for the distribution of the trial packages, training local facilitators. They serve as intermediaries between ground level field staff, participants and the researchers. Figure 7 shows the different stakeholders in the implementation process of a tricot trial.

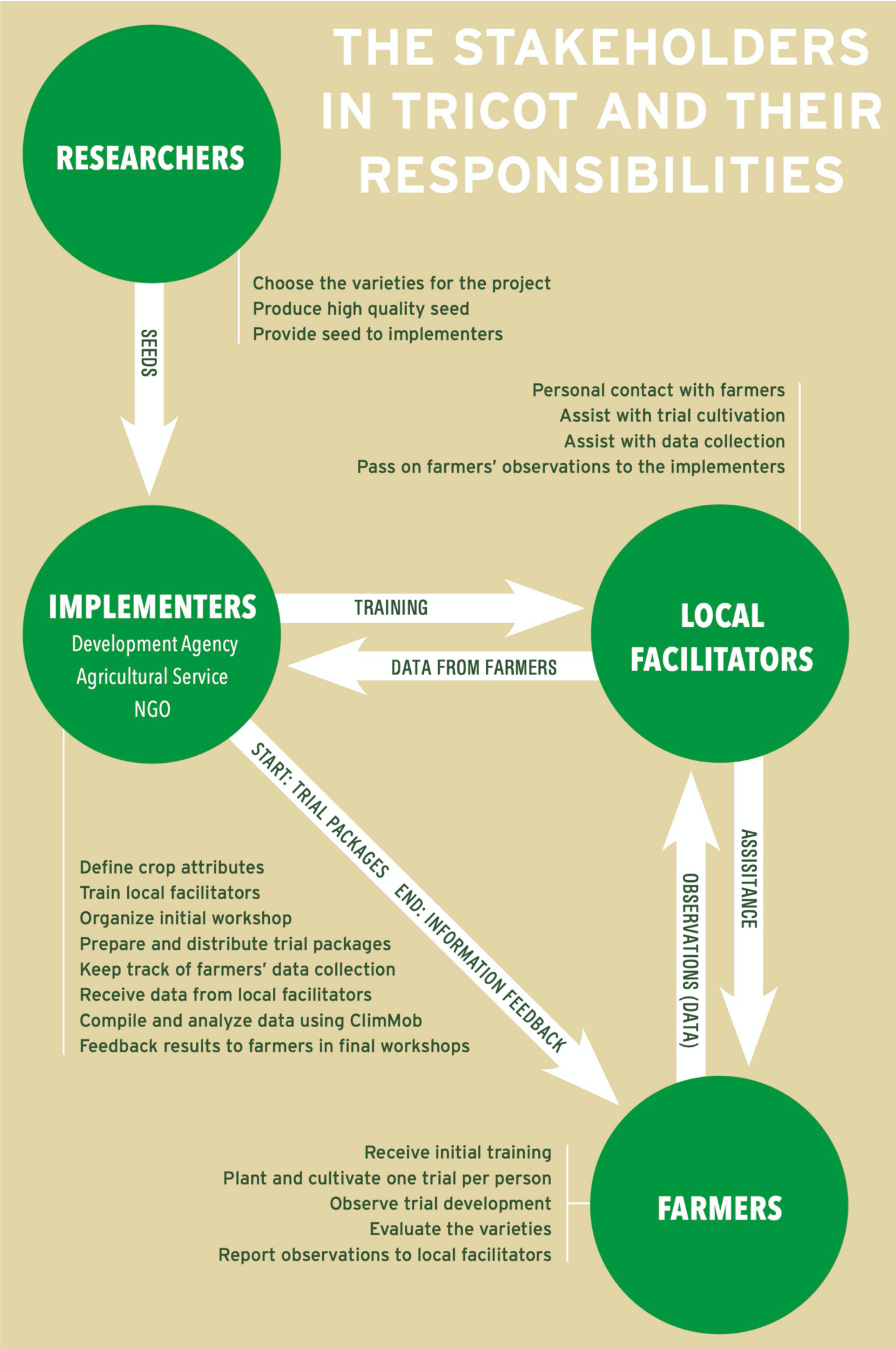


Figure 7: Implementation process of tricot trials (van Etten et al., 2020a)

The local facilitators provide assistance to participants during the trials and advice them on planting and times of making observations. They are often also in charge of collecting the data and providing feedback. Participants plant the trials and make observations. They share their data with the local facilitators.

Figure 8: Training participants on how to use the data collection format (photo: Bioversity International)

Local facilitators keep in touch with the participants by telephone or farm visits to remind them of upcoming steps in the data collection or to answer any questions the participants might have. It also shows participants that their contribution is valued. In the tricot manual the designers of the approach indicate that it is important to keep contact with participants to ensure that observations are made at the same time by the participants:

> Appropriate timing is important, and the participants should be told at what day from planting each crop characteristic needs to be evaluated. It is common to evaluate the trial in three stages: earlier-developing characteristics (for example, foliage development), later-developing characteristics (for example, diseases resistance) and post-harvest characteristics (for example, yield or market value). The project implementers should suggest the evaluation steps and dates to the participants. Many farmers have a busy life, and tricot will be one activity among many others. By telephone calls, the local facilitators may keep track of their evaluation and remind them of upcoming observation steps. The telephone calls will also help to clarify open questions, and they let farmers know that their contribution is important and valuable. Within their own capacities, the local facilitators may also support farmers directly in the evaluation at the plot (Steinke and van Etten, 2016).


Figure 9: Training participants how to observe and collect data in tricot trials (photo: Bioversity International)

At the end of the growing season local facilitators collect the data from the participants. A data collection app[2] installed on a smart phone is the suggested method of data collection, however in practice different methods are often combined, for example using phone calls or paper data collection.

The last touchpoint covers the ‘final workshop’. In this workshop the informational results of the trials are shared with participants in different communities (see figure 10). Each participant receives an individual information sheet which indicates the performance of their varieties compared to all varieties included in the trial. There is room for comparison and discussion and local facilitators facilitate seed exchanges between participants.

[2] Open Data Kit (ODK) is an open source software allowing offline data collection (https://getodk.org/) often used in agricultural research.

Figure 10: Knowledge sharing sessions after trial completion (photo: Bioversity International)

4.5 Citizen science inspired participatory agricultural research

The tricot approach builds on existing participatory research approaches, most notably participatory variety selection (Witcombe *et al*., 2005), mother and baby trials (Snapp, 2002), diversity kits (Joshi *et al*., 1997; Joshi and Witcome, 2002). The novelty of the approach lies in the adoption of the citizen science principles by involving non-scientists in experimental data collection and by breaking down the big task of variety evaluation to turn it into a mini-task that a citizen scientist can easily complete (van Etten *et al*., 2016; van Etten *et al*., 2020b). Robinson *et al*. (2018) presents a framework of standards for high quality citizen science projects which I use to evaluate how the tricot approach principles compares.

Citizen science actively involves citizens in scientific activities as contributors, collaborators or as project leaders and has a meaningful role in the project.
Tricot actively involves farmers as citizen scientists in the research process increasing their knowledge on different crop varieties or other technologies and offering them training and demonstrations on how to manage the crop. Participants act as contributors by sharing their preference data on specific crop characteristics with the implementing organization. This data is pooled, analyzed, and shared back to all participants.

Citizen science projects have a genuine science outcome. For example, answering a research question or informing conservation action, management decisions, or *environmental policy.*

Tricot trials generate data on the adaptability and acceptance levels of genotypes (in the case of crop variety testing) in specific sets of environments. This is important data for plant breeders:

> One of the goals of on-farm testing is to get insights into genetic gain achieved by breeding programs. Some aspects of genetic gain are related to traits that are highly heritable so that on-farm performance is not different from on-station performance. For example, the color of the product may not be affected by genotype by environment interactions. An aspect of genetic gain that is important as a goal shared by most breeding programs is the yield. As tricot is based mainly on rankings, generally yield estimations have been provided in that form. This provides an insight into the yield-based reliability, the probability that a new variety will outperform the current market leader, an important indicator for breeders and product managers to make decisions (Etten et al., 2020b).

Both the professional scientists and the citizen scientists benefit from taking part. Benefits may include the publication of research outputs, learning opportunities, personal enjoyment, social benefits, satisfaction through contributing to scientific evidence, for example, to address local, national, and international issues, and through that, the potential to influence policy.

The tricot approach facilitates participants to experience different varieties first-hand in their own user context. This offers huge benefits for researchers in terms of capturing the diversity of environmental conditions or socio-cultural preferences that exists between the farmers (van Etten et al., 2020a) and provides researchers and farmers with insights on the adoption and acceptability of the different crop varieties. The data captures the diversity in environmental conditions and growth performance as well as socio-economic conditions shaping technology preferences. Combining the data with secondary data on cropping and farming systems or climatic variables (f.e. Altitude, rainfall, temperature) can generate recommendations for locally-specific strategies farmers can use to deal with climate change or other risk aversion strategies.

Beza *et al.* (2017) researched different types of motivations driving participation in tricot research trials in India, Honduras and Ethiopia. Tricot participants can roughly be divided into two groups: participants who are mostly driven by intrinsic forms of motivation, for example wanting to share information, help others and contribute to science. And those whose motivations are sustained by expectation, expert interaction and community interactions. The benefits of participation in tricot accommodate both groups in terms of being able to 'contribute to science' as well as facilitating interactions between participants and possibly researchers.

However, unlike citizen-science projects where personal enjoyment can be an important driver of motivation for participants to decide whether or not to invest their time in a project, this does not seem to hold true for participants in tricot research. The physical activity of going to the field to observe the crops that were planted is part of the daily task of any farmer and therefore unlikely that they would view such an activity as a fun pastime. The authors Beza *et al*. (2017) hint at this in their article:

> Possibly, the close relation of the project with the professional activities of the participants might have created the difference here. Unlike other citizen science projects that include going outdoors to explore and record observational data in nature (e.g., bird watching), for the smallholder farmers, testing the different seed varieties on their farming conditions is crucial for their livelihood. Seed is an important production input for farmers and they would like to participate and perform variety selection as part of their main task, not as a 'Pastime' activity (Beza *et al*., 2017).

Citizen scientists may, if they wish, participate in multiple stages of the scientific process. This may include developing the research question, designing the method, gathering and analyzing data, and communicating the results.

Tricot in its current form does not offer opportunities for participants to become involved in research stages other than data collection and data interpretation. However, tricot is an iterative process where participants can grow in their capacity as citizen scientists by taking up more responsibilities in terms of recruiting and training participants and sharing knowledge on their trials within their communities. Through this iterative approach, participants have been able to influence tricot design. Either by participation and testing the approach in its early development or by actively suggesting changes in its implementation. For example, the data collection formats are a result of several iterations after suggestions from users.

> After every project cycle, the project implementers, researchers, and local facilitators should discuss how to improve the process. Including more farmers with every project cycle should be a constant objective in tricot, so that more households can benefit from the investigation (van Etten *et al*., 2020a)

Citizen scientists receive feedback from the project. For example, how their data are being used and what the research, policy, or societal outcomes are.
Participants in tricot receive early feedback on the results of the trial. Tricot informational results are pooled and shared with all participants in the trial and researchers suggest seed exchange at the end of a research cycle. Quick feedback on trial results positively affects participants' engagement and their willingness to continue experimentation in subsequent trials.

Citizen science is considered a research approach like any other, with limitations and biases that should be considered and controlled for. However, unlike traditional research approaches, citizen science provides an opportunity for greater public engagement and the democratization of science.

The tricot approach allows participants to participate in the trial under their own management. This may open up participatory research to new types of participants who in normal circumstances would not have met the selection criteria or are simply not on the radar of the implementing organizations. Simplified forms of data collection facilitate scaling of the approach making it possible to include a (much) larger number of participants into the activity of evaluating new technologies.

The tricot approach provides the infrastructure for smallholder farmers to sample new technologies to determine its suitability for their own user context. They will collect experimental data by participating in a platform that empowers hundreds of farmers to share their individual knowledge and results. For example, if a research organization sets up a trial including 50 different crop varieties, it would be difficult to facilitate a first-hand experience for individual farmers. However, if each participant performs part of the task and contributes their data, everyone will learn about the technologies and how their own sample technologies compare to the wider range of technologies. With this information, they will be better equipped to select varieties that are suitable for their specific context or needs.

Citizen science project data and metadata are made publicly available and where possible, results are published in an open-access format. Data sharing may occur during or after the *project unless there are security or privacy concerns that prevent this.*

> Open access publication of the data should be a goal of the trial. Tricot has already published a number of sizable datasets from on-farm trials (van Etten *et al.*, 2018; de Sousa *et al.*, 2020; Moyo *et al.*, 2021). Data publication could become more attractive if it is easy to do and has rewards (citations of datasets repurposed by others). Publishing all data from trials could prevent the so-called file-drawer problem, which means that only certain datasets (for example, novel analyses, striking results) are published, which then lead to biased statistics in meta-analyses. The tricot approach should address this issue by facilitating and standardizing the way in which on-farm trials are documented and published. Standardization should be done using the insights of the studies cited above. Specifically, meta-data on the trials could be standardized and some elements on the trial context could become recommended elements that are easily available from within the software (van Etten *et al.*, 2020b).

Citizen scientists are acknowledged in project results and publications.

> Participants can indicate if they want to be recognised with their name in the publications based on the data. This does not compromise privacy (names cannot be linked to personally identifiable information such as addresses, telephone numbers, or coordinates) (van Etten *et al.*, 2020b).

Citizen science programs are evaluated for their scientific output, data quality, participant experience, and wider societal or policy impact.

Monitoring and evaluation of each tricot project depend on the initiatives of the responsible organizations. Scientific output generated through the online platform of Bioversity International ensures a high level of data quality. The standardised and randomised data collection limits the number of errors individual contributors can make. Tricot guidelines suggest that each community included in the trial organises a final workshop to interpret feedback on the results of the trials and evaluate participant experiences.

The leaders of citizen science projects take into consideration legal and ethical issues surrounding copyright, intellectual property, data-sharing agreements, confidentiality, attribution and the environmental impact of any activities.

The online platform facilitating the implementation of the tricot research process is General Data Protection Regulation (EU GDPR) compliant (see van Etten *et al.*, 2020a). In general, this means the following needs to be taken into account by tricot trial implementers:

- Research ethics clearing is obtained from the relevant research institute as well as a national organization in the country of implementation.

- Prior informed consent is obtained from all participants, which would allow for data publication after anonymization.
- Participants are given the right to withdraw their participation or withdraw their data from the trial while it is executed.

The online platform used to design each tricot project, provides features to make it easy for trial designers to follow the principles and procedures indicated above.

4.6 User benefits of participation in tricot

Benefits for participants can roughly be divided into three groups: the direct benefits of the approach, enhanced experimentation skills or learning opportunities, and social recognition.

4.6.1 Receiving samples of (new) technologies

Participants receive a trial package that includes testing materials (seeds, fertiliser or other input types). Participants benefit not only from the knowledge gained during the experiment but also from harvesting these seeds which they can use directly or saved for multiplication in the following season. Furthermore, they will be able to access varieties that have become available within their community through seed exchanges with other participants. This increases the varietal diversity of a crop within participating communities.

Tricot research facilitates a low-risk method of sampling new technologies. Normally farmers who wish to change the crop varieties they plant, would have to buy or exchange seeds themselves. If these fail, they lose their money and the opportunity to grow another, perhaps more profitable crop that season.

4.6.2 Learning opportunities

Seed exchanges are common in farming communities. Participants in tricot are able to experiment with new technologies first-hand and contribute their knowledge to a common pool of knowledge about these technologies. When shared amongst researchers and participants, this can create a bottom-up flow of information that participants and other stakeholders in the community can easily spread themselves, in addition to information disseminated by researchers on the new technologies they release (van Etten, 2011).

Several other knowledge gains can be realised through participation. For example, learning basic experimentation skills of observation and comparability. Participants can replicate these skills for other crops as well. Researchers might provide additional knowledge on pest and diseases identification, planting techniques or general agronomic lessons.

4.6.3 Social recognition

Participants benefit from gaining social recognition as tricot participants. They are able to provide a service to their community by disseminating the knowledge which they gained through experimentation. They can become a source of seed or an agronomic advisor based on their gained knowledge and skills.

When more people in the same community participate (this is often the case) they can form farmer research groups who regularly exchange information. These types of interactions provide social recognition when their contributions are valued by the group.

4.7 User context

The tricot approach has been designed for use in rural communities in low-income countries and involves large numbers of smallholder farmers in their research. Whilst smallholder farmers share similar characteristics worldwide in terms of how they operate their small family farms, some elements in their daily livelihoods are distinctive to East Africa. The tricot case study presented in this chapter focuses on trial implementation in this region. For this reason, I present some of the challenges of this sub-group in agriculture below.

In East Africa, 61% of the population is directly involved in farming and over 80% of the population depends on agriculture for its livelihood. Despite its importance for rural livelihoods, smallholder agriculture faces a substantial number of challenges (Solomon *et al.*, 2018).

> The sector is still dominated by smallholder subsistence farmers, who are struggling with deep-rooted poverty and have few productive assets. Agricultural systems in the region also face environmental constraints to sustainable growth, such as degradation of soil, land, water, and ecosystems. Additional challenges include economic barriers, low human and institutional capacities, poor agro-advisory

services, political instability, conflicts, and migration. Climate change and inter-annual climate variability compound these significant challenges to sustainable agricultural growth.

The key challenges in farming are an over-reliance on rain-fed agriculture in a climate where rainfall is highly variable and arguably not enough (Kristjanson and Harvey, 2014; Nakawuka *et al*., 2018). For example, 40% of the land area in Tanzania and 80% of the land area in Kenya have a semi-arid climate (Bernard, 2001). Semi-arid climates are characterised by low levels of rainfall and warm temperatures. It is the second driest environment after arid or desert climates (Wikipedia, 2018). Biotic and abiotic stresses such as pests, diseases, droughts, and floods are common and lead to yield losses for crops and livestock. Bioversity International collaborates with a development agency focused on water and conservation in eastern Kenya and a research institution in southern Tanzania. Both locally established institutions help farmers in the region cope with drought and water shortages.

Smallholder farmers have low rates of adoption of modern technologies due to the design, delivery, and extent of commercialization of technologies. Access to extension and other support services is often inadequate (Odame *et al*., 2013). Access to new crop varieties and new agricultural inputs is crucial to many rural households. But often there are obstacles to discovering these new technologies: (a) farmers living far from the market may not get all the information about the new technologies or it is difficult to obtain them or (b) inputs sold in very large quantities making it expensive for individual farmers to buy, (c) quality inputs or varieties might not be available in local markets. Limited market access also makes it more difficult to sell produce locally. Limited access to affordable credit lines makes it difficult to purchase farm inputs and off-farm income opportunities are limited in rural areas. As a result of all these constraints, poverty and food insecurity are a reality for a large part of the rural population. To illustrate the extent of this, I present three indicators for food security, asset levels, and literacy.

4.7.1 Food security

An indicator for food security is the number of months in a typical year household struggle to find sufficient food to feed their families, from any source (the ‘hunger months’). The severity of levels of food insecurity varies per region, see table 1, however as a whole we can see that food insecurity is affecting most rural households (Kristjanson et al., 2014).

Table 1: Poverty and hunger indicators in East Africa

		Percent of surveyed household reporting:				
Country	***Location***	***More than 6 hunger months per year***	***5-6 hunger months per year***	***3-4 hunger months per year***	***1-2 hunger months per year***	***Food all year (no hungry period)***
Kenya	Katuk Odeyo	0	0	17	81	1
Kenya	Wote	44	34	19	1	2
Tanzania	Lushoto	35	27	26	7	3
Uganda	Hoima	10	9	16	35	31
Uganda	Rakai	10	25	39	15	10
Ethiopia	Yabero	53	24	18	4	1

4.7.2 Assets

Asset levels indicate a household's level of poverty, see table 2. Assets measured by CCAFS (Kristjanson *et al*., 2014) range from *energy* sources such as owning a generator, solar panel, or battery, being able to access *information* through radio, television, mobile phones, or a computer with internet access. Assets related to *production*, f.e. Owning a tractor, mechanical plough, *transport* means such as bicycles, motorbikes, cars or trucks and owning *luxury items*, f.e. A fridge, improved stove, air condition and having access to a bank account.

Table 2: Poverty and asset levels for surveyed households in East Africa

		Percent of surveyed household reporting number of assets:		
Country	***Location***	***Basic (zero)***	***Intermediate (1-3)***	***High (4 or more)***
Kenya	Katuk Odeyo	11	66	23
Kenya	Wote	9	47	44
Tanzania	Lushoto	16	79	5
Uganda	Hoima	9	63	28
Uganda	Rakai	10	66	24
Ethiopia	Yabero	62	37	1

4.7.3 Literacy

Education is important to farm production, especially in enhancing people's abilities to adopt new farming practices or technologies. Rural populations in East Africa have lower levels of literacy compared to people living in urban centers (Naimasia, 2015). Smallholder farmers are not always able to fully benefit from the existing educational infrastructure for a variety of reasons. The indirect or opportunity costs of attending schools for young adults might prevent them from finishing secondary school. Furthermore the distance to school, poor education quality in terms of outdated curriculum, unavailability of education resources, untrained teachers, or poor school management might limit the opportunities for children to obtain an education. Kenya in contrast scores relatively high compared to other countries in East Africa with 95% of the children attending primary school and 33% of the population completing secondary school. However, high rates of unemployment still persist amongst the young population (67% for people aged 15-35 years old) (Habitat for Humanity, 2017).

4.8 Conclusions

Tricot is a citizen science-inspired participatory approach to agricultural research for crop variety evaluations. The approach makes it possible for farmers to experience a range of three different varieties on their own farm, share this knowledge and learn about other varieties from other participants. It is important to test varieties in their use environment to increase the external validity of the experiment and the tricot approach allows researchers to scale up the number of trials they can normally conduct. Several design choices make this possible: the experiment design of randomised blocks of three choices and the visual materials and digital data collection format simplifies data collection and facilitates quick data analysis. Tricot uses citizen science principles, not only in terms of crowdsourcing data collection, but also offers valuable learning opportunities to its participants. Tricot is implemented in rural areas in low-income countries and targets smallholder farmers. Farmers in these regions typically have to deal with many challenges; low adoption of modern technologies, limited access to information and inputs, low literacy rates and challenging farming conditions in semi-arid regions.

Chapter 5

User experiences in participatory trials

5.1 Introduction

In the previous chapters, we identified that barriers to participation are a recurring issue in participatory agricultural research. Tricot trials offer a novel approach to participation through their alignment with citizen science principles, however, they might not be exempt from some of these barriers. The participatory design focuses on designing democratic and inclusive processes for involving stakeholders and as such the field has performed considerable 'rethinking' on participation.

I make use of participatory design methods and tools (see section 3.3) to discover the drivers and hurdles to participation in a recently completed tricot trial in Tanzania. Data collected from an actual tricot implementation with its flaws and its deviation from the tricot implementation guidelines serves as a realistic case for uncovering pain points and therefore will generate valuable information for the design process. Empirical data was collected in a series of user interviews with tricot participants to understand what aspects of the tricot approach enhance the experience of participants or serve as pain points in the user journey. This is a term used in software development and refers to the *journey* users go through when interacting with a service. Discovering the user experience and extrapolating common attributes, helps to define the problem space and where the opportunities for design lie.

This phase in the design process represents a combination of primary research and secondary research to understand the situation or context and what defines the challenge. This is far from a linear process, rather doing 'the homework' to prepare for the next phase (see figure 11)

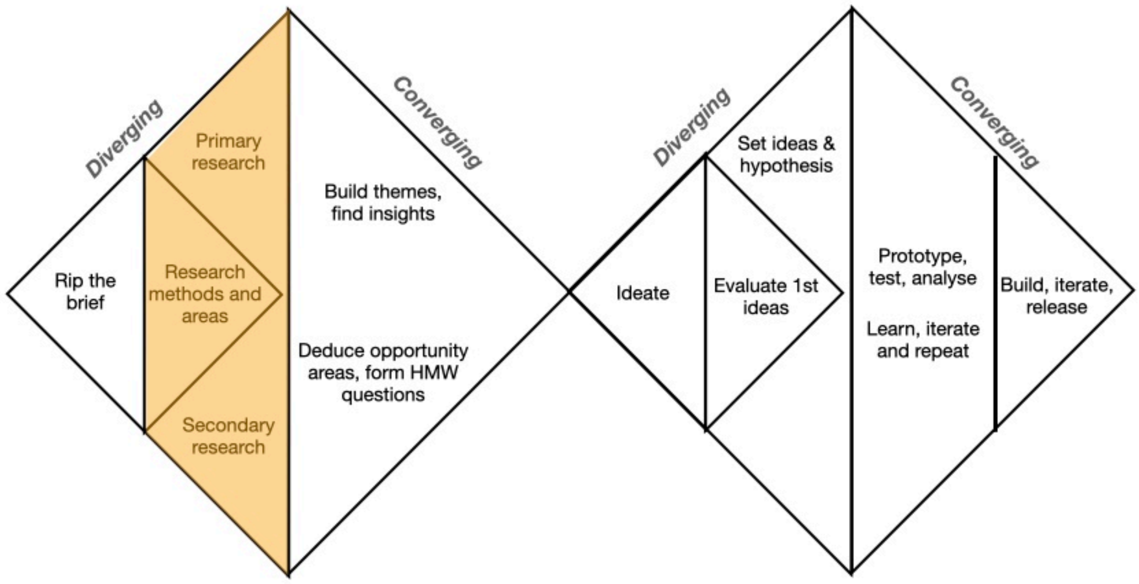


Figure 11: Stage 2 in the design process

The key questions around barriers for participation are:

1. What are the drivers and hurdles to participation in tricot trials?
2. Why do participants choose to participate or continue or discontinue their participation in tricot trials?

To answer these question, I designed a interview study with recent participants and non-participants in the tricot approach as this would allow me to collect in-depth knowledge on how participation in a tricot trial was perceived by users and what they described motivated their participation. This field study was carried out in southern Tanzania where they had recently finished a second tricot research cycle. I was familiar with the research organization as I provided them with training and support during the first tricot research cycle and this made it easy to arrange support for setting up interviews with the respondents.

Conducting interviews with users is a relatively quick way to collect insights into how users feel about participating in research. For example, how do participants feel about the activities they participated in or about the information they received? Or about the value being offered by participating in the research process? How do they feel about participation in general? These are straightforward questions. By taking the respondents through the research cycle step-by-step I was able to identify if there were any hurdles in the user journey. The methodology described by Vanden Abeele *et al*. (Vanden Abeele *et al*., 2012) using laddering techniques was instrumental in uncovering some of the values and behaviors of the users, as shown in this chapter.

Data is presented in two parts. First, I use a *phasic* lens (Saad-Sulonen *et al*., 2018) to identify and reflect on the different phases or steps of the user journey of tricot participants. The phasic lens is a concept taken from the field of participatory design. Looking back and examining the different phases of activity, in particular focusing on the interactions between participants and the artefact they interact with, allows us to identify the multiple realities or needs of specific stakeholders. Rather than examining an approach for its impact or outcomes, which takes into account the purpose or the perspective of the developers of the approach or the researchers implementing it, this gives a more user-oriented perspective. Comparing an actual tricot implementation with the suggested implementation guidelines (van Etten *et al*., 2020a) reveals deviations from its intended use. By taking a step back and determining the ideal state for this particular context in terms of its implementation, I am able to examine what users need or which challenges they face when trying to complete their own mini-trial. The *ideal state* refers to the most optimum scenario in a given context and therefore might not be the most practical approach to implementation. However, by envisioning the ideal state and considering user needs and potential challenges you can design towards a future state, a state where the conditions of researchers and users are met (Akbar, 2016). We cannot assume we already know what the future state should be without taking into consideration the experiences of the users and the situated challenges of the approach.

Secondly, I analyze the motivations driving participation of farmers in tricot trials by exploring the expectations users hold and to what extent they feel their expectations have been met. In addition, I present what drives participants' decisions to volunteer, to 'drop out', or to sustain their voluntary contributions.

5.2 Methods

5.2.1 Project context

Researchers from Naliendele Agricultural Research Institute (NARI) based in Mtwara, Tanzania assisted with the logistics of the interviews. NARI has the mandate to conduct agricultural research that addresses the needs and aspirations of the farmers, particularly improved crop and livestock productivity. For the *tricot* trials NARI's research focuses on breeding new groundnut varieties which are less susceptible to drought and pest and diseases. NARI has been conducting farmer participatory research in the Southern Research Zone[3] since 1970. Farmer research groups work together with researchers who provide them with information on how to set up experiments and how to collect and record data. They are advised to have weekly meetings with other members of the group to discuss the findings from their experiments. At the time of the interviews, two cycles of tricot had taken place. Varieties of groundnut were first planted in a demonstration farm for the multiplication of seeds before the first cycle started. Demonstration farms are local trials to introduce new technologies or showcase a range of crop varieties. In this project, researchers initiated the demonstration farms and provided training on planting and spacing of the groundnut crops and pest and disease infestation and treatment. The farmer research groups managed the trials. Not all participants were able to contribute to the individual trials, however, they would be able to gain experience and knowledge about the trials from the demonstration farms.

The first *tricot* cycle started in 5 villages with 10 farmers participating from each village in December 2015. They tested 6 varieties of groundnut. In the second year, they increased the number of trials to 100 participants testing nine varieties.

5.2.2 Recruitment of respondents

For this interview study, we recruited 6 participants of the recently completed *tricot* research cycle as well as 6 non-participants. All participants were 18 years or older. The interviews took place in Masasi town, approximately 160 km inland from its nearest city Mtwara in southern Tanzania and 55 km from the border with Mozambique. Affiliation with the host institution NARI guided the participant sampling. The primary recruitment criterium was prior knowledge of the approach either through participation in the previous research cycle

[3] Tanzania has seven agricultural zones each with its own research station (sometimes more than one) carrying out research according to set research priorities and with predetermined commodities assigned to the area.

or indirectly by participation in farmer field days.[4] Furthermore, gender and location of the trials were considered in the sampling strategy to ensure diversity. The village executive officer contacted the (non-)participants by telephone or a personal visit prior to the interview date to select an appropriate time for the interview. The twelve farmers were informed that there would be a group meeting on July 20th, 2017. They were told that there would be someone to ask them questions about the *tricot* trials, no other information was provided. No remuneration was offered. Consent was taken before conducting the interviews. Collecting thick data (as in quantity) is a standard practice in agricultural research to increase its validity, however, considering the purpose and the timing of these user interviews, a total number of twelve interviews was deemed sufficient to generate rich data into the user experience. To achieve data saturation, I used open-ended conversations with individual users rather than focus group discussion as it provides insights in the individual user experiences. The insights presented here are based on the experiences of twelve tricot users and are a first step in information gathering of a design process (Hall, 2013; Fusch and Ness, 2015).

5.2.3 Procedure

I conducted semi-structured face-to-face interviews. See appendix 1 for the interview guide. During the twelve interviews, I took analog notes, and with the explicit permission of the subject, the interview was audio-taped. The data collected from the interview and the questionnaire were anonymized. Including the consent process, introduction, and closing, the total interview time took between 30-40 minutes for each participant, with no other activities. The interviews took place in the ward office at a central location within the community. All interviews were conducted by myself with the help of Athanas Minja (NARI researcher), who also acted as a translator.

Participants were asked to describe their experiences with a recent *tricot* project. Interview questions addressed each step of the process to investigate the user experience of the actual implementation (planting and other agricultural activities), the data collection, the interaction with field officers or researchers, and the feedback they received. The

[4] Field days are educational events organized and hosted by a agricultural producer, often in collaboration with agricultural extension. The events usually include demonstrations of specific management practices and equipment and/or highlight research methods and results.

interviewers guided the participants through the tricot research process, asking them to describe how they heard about the trials and what made them decide to participate. I prompted the interviewees on what happened, how it made them feel, and what would be considered to be difficult or rewarding in the process. I asked them to talk me through the process of doing an activity (e.g. Planting, making observations, filling the data, handing over the data). I asked questions on the implementation of the project; how many contact moments they had with researchers and field staff and if they received feedback or results from the trials. Plus, I asked them how they would like to receive feedback on the results (regardless of whether they had already received feedback) and if they had any other suggestions for improving the approach.

The group of non-participants were asked to explain how they heard about the trials and what information they received from any sources (research staff, village executive officers, neighbors). I prompted them to share what made them decide not to participate and at what moment they made that decision. I asked them if they had to provide any information to the organization and if they would decide to participate given the opportunity.

I made it clear from the start that this interview was more about the evaluation of the research approach and had little to do with their performance in conducting the trials. Occasionally the question wasn't properly understood by the translator and rather than pushing the point, sometimes I left this topic to move to the next as we had limited time with each respondent. Interview questions often revolve around quantifiable activities, determining input use, or crop evaluations using established forms of measurements. Asking respondents to recall their experiences of being involved in the trials, requires respondents to formulate different types of answers. Multiple biases may influence the perceived user experience, most notably the discrepancy between how users feel during the experience and how they recall it afterward (Cockburn *et al*., 2017). Users remember the most intense moments of the experience better, the so-called 'peak-events' and along the same line of thought, bad interactions are easier to recall than positive ones (Kahneman *et al*., 1993; Cockburn *et al*., 2017). We need to take this into account when we evaluate the pain points brought forward in this chapter. Most likely the positive experiences outweigh the negative impressions, however, these experiences are not brought forward (as much) during the interviews. If something works, we don't often stop to figure out how it works and quite possibly take these interactions or mechanisms for granted.

5.2.4 Limitations of the interview study

The interviews took place over the course of two days in 2017. Whilst I would normally opt for individual interviews at people's homes, the research organization decided that the interviews would take place at the ward's office as I was heavily pregnant at the time. In rural Tanzania, a ward is an administrative unit consisting of several villages and is an official place of business. It would not be the usual place for the farmer research group to meet and this created a more formal atmosphere for the interviews. Ideally, user interviews take place in a use context - at the place the research takes place as this makes it easier for the user to show the interviewer how they conducted the research and what issues they might have had during the process. That is not to say that the user interviews didn't generate reliable data. By organizing the interview questions according to the different stages in the research process, respondents were able to recall what they did during each stage. Respondents were able to communicate the pain points they found most important clearly to the interviewer.

5.2.5 Data analysis

Audio files collected during the user interviews, were transcribed by Jerusha Achieng, a co-worker from my office in Nairobi, Kenya. Data from analog notes and the transcribed interviews were compiled into interview data files. I used thematic analysis to identify, analyse and report themes within the data. I follow Braun and Clarke's (2006) guidance on conducting thematic analysis. During a first exploration of the data, whilst reading the interviews, I generated the initial codes and aimed to cluster them into broad themes. See figure 12.

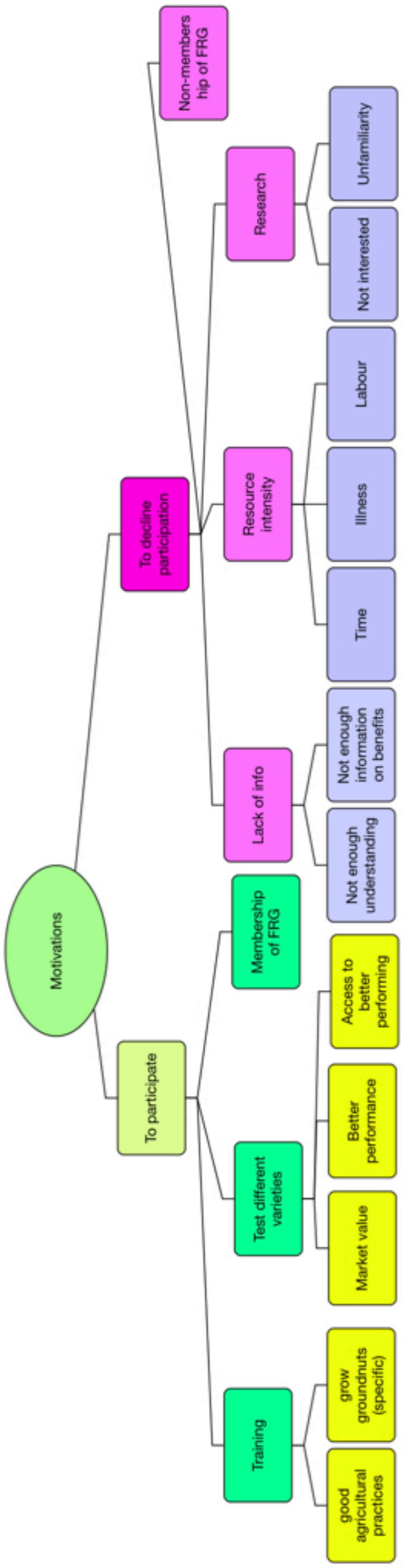


Figure 12: thematic map of the coding process

Then, a coding scheme was used following each of the steps in the tricot trials in chronological order. Codes consisted of ‘heard about trial’ , ‘registration’, ‘planting’, ‘data collection' and 'receiving feedback'. When attributing the codes into the different themes, additional themes emerged, for example 'situational factors' was added for issues mentioned about trial implementation that fell outside any of the categories. I then redid the coding scheme in a second round of coding, focused on the 'reasons for participation, 'benefits' with subcategories of 'expectations not met' and 'training' and 'suggestions outside tricot scope' based on a model examining sustained volunteerism (Penner, 2002). I chose to present a collection of quotes before presenting the themes derived from the analysis. Whilst this might at first seem repetitive, I did this because I wanted to present the unbiased data first, for the reader to be able to immerse themselves into the realities of tricot users before interpretations were given. The data derived from coding is modeled in different ways. First, the user journey of this particular tricot implementation is compared to the suggested implementation guidelines from the developers of the approach. Second, the reasons for non-participation, initial and sustained participation are presented. The themes are presented in the discussion and all relate to the overarching research questions (1) What are the drivers and hurdles to participation in tricot trials? And (2) Why do participants choose to participate or continue or discontinue their participation in tricot trials?

Sampling

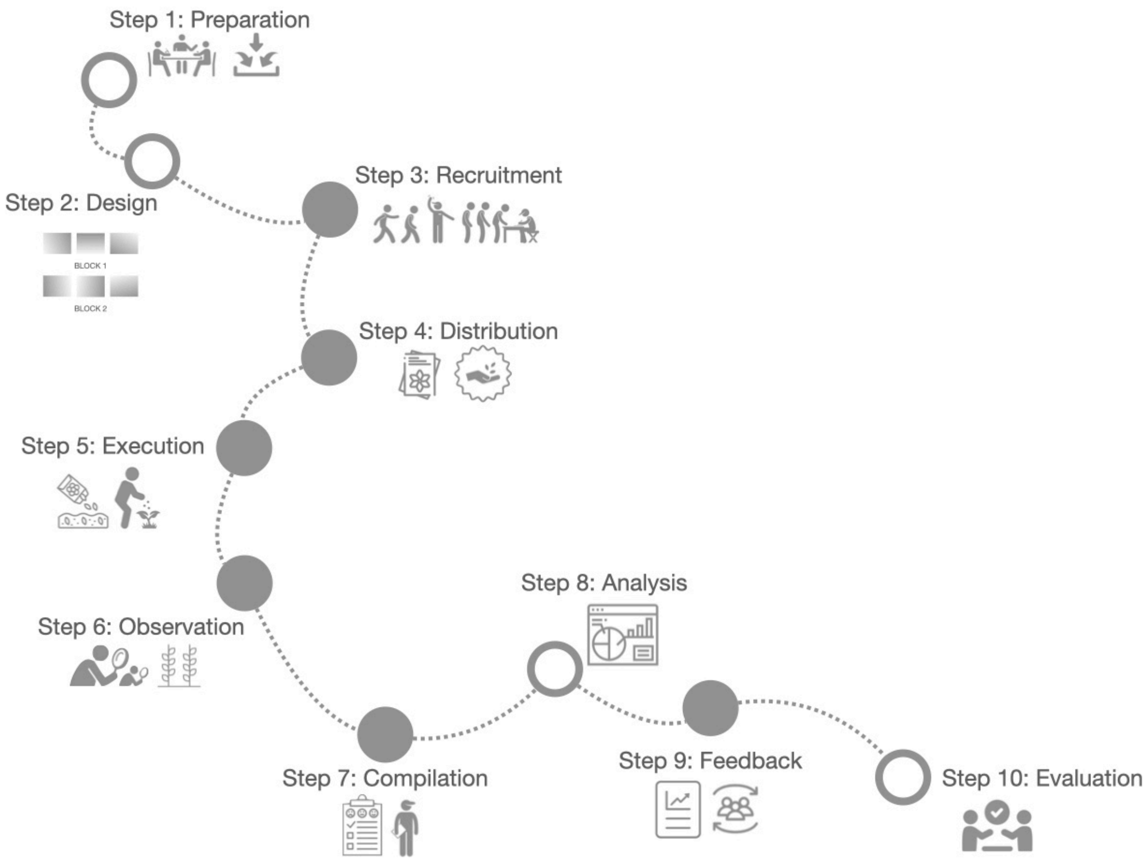
Respondents for the interview study were selected based on their affiliation with tricot research. An equal number of participants and non-participants were selected for the study. During the data analysis, the respondents were categorised into sub-categories. See table 5.1.

Table 5.1: number of interviews per participation category

Participation category	Number of interviews
1. Chose not to participate	1
2. Wants to participate	5
3. Participated but did not complete the full cycle	1
4. Completed a full cycle but chose not to continue	1
5. Completed a full cycle and wants to continue	4

5.3 The tricot research process

This section presents the data from the user interviews where I asked recent participants in a tricot trial to explain the research process as they experienced it. The tricot guidelines present a series of ten steps to develop and implement a tricot trial (van Etten *et al*., 2020a). Figure 13 describes each step in the tricot research process. When viewing the research cycle from a user-perspective these steps present the whole process, from pre-project time (step 1-2) to project time (step 3-9) and post-project time (step 10). Using a *phasic lens* to look at the user journey creates an understanding of how participants in the tricot research process ‘experience’ their research journey. By pulling together fragmented pieces of information I aim to visualise an entire experience from the perspective of the user. Guiding questions are: What steps in the research process drive participation? And what steps present hurdles for participants to fully engage in the research?



Step 1: Preparation
Researchers define a set of comparable technology options to test. They provide the necessary materials to project implementers. They train the project implementers on how to use the Climmob online platform.

Step 2: Design
Project implementers use the ClimMob online platform to design the experiment, generating a randomised list of combinations of three technology options for the individual trial packages and for project management and data overview

Step 3: Recruitment
The implementers recruit dedicated farmers interested in improving their farming through the use of new technologies.

Step 4: Distribution
Farmers are trained in the tricot approach and on how to collect data. Each farmer receives a trial package of three technologies to be tested.

Step 5: Execution
Farmers use their trial packages to apply the new technology options separately, on small plots next to each other, in a mini-trial on their own farm. To avoid any bias, they are not aware of the names of the crop varieties or other technology options they are testing. These are revealed to them only after the data has been collected

Step 6: Observation
Every farmer is responsible for their own trial and makes various easy observations about their three options over the course of the season. For example: Which variety had the highest or the lowest yield? The farmers record these observations on an observation card.

Step 7: Compilation
The local designated field agents collect and compile the observation data from the tricot farmers, either in person or by phone. They record the information digitally and send them on to the implementing organisation. For this, they can use the free 'ODK Collect' smartphone app, which is connected to the ClimMob software.

Step 8: Analysis
The implementers compile and analyse the data from the trials, using the ClimMob online software, to identify which technology options showed the best performance and under which conditions.

Step 9: Feedback
The implementers provide feedback to every participating farmer: the names of their three technology options, which options were most suited to their farm (out of the three options tried by them and out of all the options tried by farmers throughout the project), and where to obtain them.

Step 10: Evaluation
Tricot is an iterative process: after every project cycle, researchers, implementers and farmers collaboratively evaluate how the process may be improved in the next cycle

Figure 13: The 10 steps of the tricot research journey

I focus on the steps where participants have any direct or indirect contact with the research, researchers or implementing agents, the so-called *touch points* in the user journey. This leaves out step 1-2 and 8 which are carried out by researchers and project implementers without participants' inputs.

Step 3: Recruitment

The first step in which potential users come into contact with tricot research is when implementers start recruiting dedicated farmers to participate in the tricot trial. Implementing organisations might recruit participants through its own network or the network of local partner organisations. They might, as suggested by the tricot guidelines, also hang posters in agricultural shops, village halls or corner shops or contact existing groups in the farming communities to attract farmers to volunteer their participation.

According to the tricot guidelines (van Etten *et al.*, 2020a) any farmer who wishes to participate should be able to get involved in a tricot experiment. Having 'many motivated farmers is key to the success of the project'. Researchers collaborate with local facilitators who help to identify and recruit motivated farmers. Ideally farmers participate more than once in different experiments and across different seasons.

In contrast to the ideal state which follows a citizen science bottom-up approach to recruitment, the recruitment process in this implementation was initiated by researchers through village executive officers[5]. The village executive officer got in contact with the lead farmer(s) of the different farmer research groups to explain the purpose of the tricot trial and to ask who would want to participate.

> He got information that some researchers were coming to do research on groundnuts. They were advised to form groups because the researchers were going to work with them in groups and from there they would be given information and training about groundnuts - interview 4.

People who were not members of the farmer research group were not able to participate.

> She never got an opportunity to join the farmer research group. Each group has a limited number of members and the members were already chosen. She doesn't know how many members each farmer research group has. Given a chance she will join. Only the leaders know the actual number to join the group - interview 5

> When the trial information was passed to them in their group meeting, they were asked if they wanted to join and be part of it, they did not want more than ten people. So ten members volunteered - interview 10.

Focusing solely on participants from existing farmer groups can constrain regular implementation. The research organisation only allows ten people to participate in the tricot trial in any research cycle, often asking participants with previous research experience to participate in subsequent cycles. This doesn't leave much opportunities for other interested farmers to get involved in the tricot trial. Whilst it makes sense to limit the number of participants in a farmer research group as it requires substantial training and support to sustain their ongoing research efforts, it might be problematic when the same principle is applied to tricot implementation as it follows citizen science principles to facilitate

5 In Tanzania the village executive officer is a government appointed official who together with the elected councillor operates the village council. It is the lowest administrative unit

participatory research implementation at a larger scale and requires a diverse group of participants to obtain tricot data.

Step 4: Distribution

This step in the research process consists of training participants on how to implement their own mini-trials and how to collect data. It is also the moment where trial packages are distributed and participants are registered with their name and a unique code linked to their trial package. The online platform uses this data to provide individual feedback on the results at a later stage in the research process. These activities are often combined into a single workshop.

Training workshop

The tricot process starts with a workshop where participants receive their trial packages and learn about the *tricot* research process. Ideally the training should take place well before the start of the trials with a maximum of 20 farmers per workshop. The project implementers together with the field agents invite interested farmers to a central location to explain the *tricot* trial, and the benefits and responsibilities of participation. The *tricot* guidelines suggest to plant a demonstration plot nearby so people can see a trial in action or to show one of the educational videos of *tricot*.

Participants are registered in an app by the field agents. The minimal data requirement for each participant is the name of the participant and the trial package code. However, additional data in terms of household and farm characteristics can be added when configuring the app for each project.

Two respondents indicated that the earlier training did not provide sufficient information for them to carry out their trials as intended:

> After they were chosen they received a package with seeds and an instruction sheet, no information was further given - interview 10

> They have not been trained well. Researchers did not come and visit them often. They did not get enough information about pests and diseases (…). Researchers should continue in giving them more training so that they can be able to know better ways of growing the crops / become better groundnut producers - interview 12.

The lack of instructions also hindered participants' ability to collect data. Specific mention was made on the questionnaire used to collect data:

> They need someone to help and guide them on how to answer the questions. Reading the questions and answering them at the same time is not easy. The form is also too long and should be shortened - interview 8.

Distribution of trial packages and registration of participants

Participants received three different groundnut varieties and were asked to plant these varieties together with a local variety. The trial packages were distributed blindly.

> Each participant gives their preference for a number and they are given that envelop. They don't know the seed type since they are packed and can't tell (…). Each participants give their preference for a number and they are given that envelop. They don't know the seed type since they are packed and can't tell - interview 12.

Step 5: Execution

Farmer groups received directions on the spacing of the groundnut crops when planting the demonstration plots. No specific training was provided for the individual trials, considering that all farmers involved were also involved in the demonstration plot.

> She was directed on the spacing of groundnut and shown the different groundnut varieties for planting. After the crop was planted she was shown the germination rate and the yield. They also looked at different pests and diseases that occurred in the different varieties. She was instructed on how to control termites. *She is referring to the demo plot which was planted as a communal activity in the farmer research groups prior to tricot implementation* - interview 3.

Participants plant and manage their trials on their own without much intervention from field staff. Data should be collected on trials that mimic regular farming practices, not on farming practices as directed by researchers or field staff. To ensure this, *tricot* provides two basic principles to trial planting: (a) the trial should be part of a farmers' regular production without receiving special attention or being neglected, (b) the three different varieties and the local variety should be planted next to each other to ensure fair comparisons.

Each farmer planted almost three rows of approximately two to three meters long for each variety. The number of rows varied however within and between farmers' plots, depending on the amount of seed given for a particular variety. The process of planting the individual trials was considered to be an easy process. Respondents explain the process of planting the individual trials:

> First we prepare the field, then we wait for rain. When rain starts we plant the seeds and wait for germination. After germination of the crop, it is time for regular weeding. We also go to the field to look for diseases (e.g. Any pests or crop diseases that effect the growth of the crop). We uproot plants that appear to be affected by pests or diseases. (When fully grown) we select plants and store seeds for the next season. Then we harvest all and shell for planting in the next season. Some of the crop is used for selling and some of the crop is used to prepare groundnut flour - interview 3.

> They got three types of seeds and planted the same way as they did on their demo plots (…). They demarcated the trial as per specifications from the instruction sheet and planted the trail. They had six different kinds of seeds [*he is talking about the demonstration plot*]. In the first cycle they had to make three rows in each plot for the six different varieties. Spacing: 10 cm plant to plant and 15 cm row to row. In the second cycle they planted 5 rows of each variety + an individual trial of three varieties - interview 10.

Seed quality was poor, especially in the first cycle. The seeds didn't germinate well and they ended up with a poor harvest. During the second cycle the germination rates were better. Two farmers mentioned that the seeds they received in their package didn't look proper ("they were rotten", "the seeds had shrunk"). They also complained about the disease susceptibility of certain varieties. Participants had to uproot quite a few plants.

> They received them in envelopes. Some seeds have shrunk (?) And were rotten, some did not do well when planted and some were tiny as compared to the normal size - interview 12.

Step 6: Observation

Each participant received an observation card for their individual trials. Three respondents (of the six respondents who participated in the trials) indicated that they did not visit the fields to make explicit observations as part of their participation in the *tricot* trials. Observations are made implicitly whilst tending to the crop by performing tasks such as weeding or when checking if the crop has been infected by pests or diseases. This is part of their normal routine. The farmers did not keep records of observations made during this process.

> Normally she goes to the field every morning and evening to observe. She went

> twice specifically to write things down. Other farmers came to her farms and together they made the observations and filled the forms. Collectively they agreed on the variety that they found useful [*she is referring to the demonstration farm*]- interview 3

> She filled the observation card at home, not in the field. She filled the form in one go. They got the forms early but only filled them after the harvest - interview 8.

Participants are asked to record specific observations about the crops, varieties or planting techniques they are asked to compare. They are asked to focus on one criteria at a time, for example 'which of the three varieties is least susceptible to pests?'. Different criteria should be observed at different times; germination rates should be observed when the seedlings emerge from the soil whilst market value is determined after harvesting. The *tricot* guidelines suggest that it is useful to follow up with participants with a phone call to remind them of upcoming observation steps.

Respondents indicated that they did not fill the form in the field, but at home, during the field days, or when other members or the extension officer visited their trial. All six participants indicated that the form was filled after harvest. One respondent indicates going to the field to make observations, which makes data collection a more explicit approach:

> Normally she goes to the field every morning and evening to observe. She went twice specifically to write things down. Other farmers came to her farm and together they made the observations and filled the forms - interview 3.

However, when probed when she filled the observation card, she indicates that it was filled on her behalf:

> [when shown the observation card, she explains that researchers from NARI came to explain the form but it was the extension officer who filled the information] - interview 3.

One respondent indicates that filling the observation card is an easy process. However, even she received help with filling the form.

> It is easy to fill the form. They were given directions on how to fill the form after harvest. She did not read the form in-depth (…). Last cycle she did not fill the form because she was hospitalised (…). The group leaders should visit all the groups individually so that they can fill in the forms together - interview 9.

Two respondents indicated that they did needed more instructions to clarify some of the questions on the observation cards:

> She filled it but she could not understand some of the questions asked. She needed more instructions (…). They need someone to help and guide them on how to answer the questions. Reading the questions and answering them at the same time is not easy. The form is also too long and should be shortened - interview 8.

> The form is difficult, we need proper elaborations to understand each question. Some questions seem like a repetition (…). You have to be very keen when answering the questions to avoid answering questions that you might think are similar yet they are very different, it is not easy filling it. - interview 11.

From the respondents we understand that observations are made during routine visits to the fields. Observations are not made explicitly at set times during the growing season. This might be due to a lack of instruction or follow up by the local facilitators or unclear instructions in the observation cards.

Furthermore, respondents indicated that the forms were filled after harvest only when asked to do so by the local facilitators. Two respondents indicated receiving help with filling the forms. This may compromise the validity of the data, especially when forms are filled in a group setting which limits the benefits of having individual observations leading to more accurate results in the overall tricot trial.

Step 7: Compilation

The local field agents will compile the farmer-generated observation data. To do so, they have different options, including using ODK-based forms generated by climmob. Some alternative options for data collection can make the process more efficient. Some of the different options include:

- Visit farmers, inspect observation cards and transcribe farmers' observations directly to the ODK Collect App.
- Take photos of the observation cards to copy the data later directly into your database or input the data using ODK Collect App. Remember to write down the farmers' name and package ID with the number of each photo.
- Call the farmers on their own or their neighbours telephone and fill out the form in ODK based on the information transmitted by the farmer during the call.

The observation cards were collected during field days after harvest.

> The forms were all collected on the last day when they had a gathering with all the group members [*field day organised by the researchers*] - interview 8.

There was no mention of digital data collection by the local facilitators, from the respondents. I later verified that data was collected by taking in the observation cards and entering the data into the database online. Manual data entry can be tedious and might cause delays in the subsequent steps of data analysis and delivery of feedback on the results.

Step 9: Feedback

The *tricot* guidelines suggest that in order to disseminate the results of the trials, the implementation partners organise a final workshop to discuss the results. In the workshops field staff together with the implementation partners present the overall result and provide the individual results on a so-called feedback sheet to the participants. They are given time to discuss their results with other participants. They also receive a practical agronomic lesson as an incentive for participation. For example field agents or extension workers explain about seed storage.

Two cycles of *tricot* trials had passed at the time the interviews took place, however the researchers had not reached out to the participants to share the results of the trials. Three respondents indicated that they would like to know what happens after the trials.

> They would like to know what happens after the trials and after they have succeeded on the trials they would want to know how they will benefit - interview 10

> She expect researchers to come eventually since the research is still ongoing. She wants to know which variety if preferred in the market - interview 12

Participants did not receive formal feedback on the trials, however they were able to collectively evaluate the trials and compare which varieties performed better during field days. They also share information about the performance of the varieties amongst themselves:

> They all gathered together and shared the information from the trials. They agreed collectively on the variety that they found useful. - Interview 3.

> All group members visited each others farms and collectively they decided on the

overall results. They compared their results with each other in the group. They made observations on all their farms to see what everyone has done - interview 8.

She has never been visited on her farm but they do discuss the results during meetings with the farmer research group - interview 9.

The farmers have had different experiences with their trials, so reciprocal sharing of these experiences with other farmers is an important part of the learning process.

There seems to be trust that NARI researchers will come back to the area to discuss the results. Although one farmer expressed his hope of having more frequent interactions:

> Do not neglect the projects that you have introduced. They should not introduce ideas and disappear but should come back and do the follow-ups. Researchers should visit during the trials. They can't just assume everything is going well - Interview 10

Delivering (quick) feedback on the results is imperative to sustain participants' motivation in the long run. Without obtaining the names of the three varieties each participant grew as part of their individual trial, and which options were found most suitable according to the rankings of all participants, they will not be able to benefit from the information generated by the trials nor will they be able to obtain the varieties that they would like to grow themselves (if they do not know the names and performance of these varieties). The benefits of the trials are then limited to being able to trial new varieties themselves and sharing this information within their own farmer research group. Respondents indicated that they are eager to receive the results of the trials for the following reasons: (a) comparing the success and failure of the trials; (b) to know which seeds did better than others; (c) to make a more informed choice on which seeds they should use on their own farms; (d) how to deal with pests and diseases.

> They want to compare the success/failure of the trials. They can compare notes from the different groups that are involved (…). Researchers have to meet with the group members and tell them which seeds did better than others. They should be able to compare all the seeds and pass the information back to them so they know which ones are better and to be used. So far they do not know which seeds did better since no information was give to them concerning this. Researchers should do follow ups and give advice so that they can know where to improve and how to go about certain

> disease outbreaks. Instead of using lead farmers or agents, researchers should go directly to group members and pass information through the groups - interview 11

> Yes, include the challenges like pests and diseases on the groundnuts (specifically Rosetti disease) and information about the spacing of the crop. For example now they place the crop closer together which can help prevent infection of the plants. Market information should be included in the form. This will motivate people to join the group - interview 9.

I asked the respondents how they would like feedback on the results to be delivered. The participants are already working together in farmer research groups and meet regularly to discuss their research findings. Therefore it seems logical to use this network to distribute and relay the feedback on the results. However, this only works when all participants are part of the farmer research networks. When the tricot trial is scaled up to include farmers outside of these networks, data collection and feedback delivery face additional challenges.

> The group leaders should visit all the groups individually so that they can fill in the forms together. She would like to keep a copy of the form herself - interview 9.

> Lead farmers in their groups are the ones who give them the information. So any information can be relayed through them (…). Instead of using lead farmers or agents, researchers should go directly to group members and pass information through the groups - interview 10.

> Through a meeting by sharing the information and experiences - interview 11

5.4 Reasons for participation, non-participation and sustained participation

Using a phasic lens to scrutinise the user journey did not provide information on the motivations underlying participation. Here we list the reasons for non-participation, initial participation, sustained participation and for discontinuing participation after initial participation based on five participation classes as shown in the methods section (see table 5.1). Guiding questions are: What drives people to get involved in research trials? What benefits do they expect in return for their participation? What issues cause people to decline or drop out of the research process?

5.4.1 Reasons for non-participation

Not everyone had the opportunity to participate in the trials. Three respondents were able to be part of the group of people who were involved in the demonstration farm and thus were familiar with the researchers, however they were not part of the group of people selected to participate in the individual mini-trials. Two respondents were not informed of the research when it was ongoing. Participants also requested to 'open up' the approach to include more people in subsequent research cycles.

The most important reasons for deciding not to participate in the initial onboarding stages are (1) insufficient information before the trials on the benefits or (2) not being able to meet the responsibilities of participation. Personal challenges preventing participants to continue their trials. Two of the respondents were unable to attend regular meetings and were asked to leave the group.

5.4.2 Reasons for initial participation

Reasons for initial participation can be summarised in the ability to gain knowledge and benefit from training, benefit from increased access to seeds or other inputs, the ability to generate income from the trials, and group benefits.

Participants are interested in participating in research because they expect to be able to improve their cultivation practices from the training they receive from researchers. They are also interested in observing the performance of different varieties of groundnut and comparing this with their local variety and benefit from increased access to seeds or other inputs which might allow them to generate income from the trials. Furthermore they expect increased access to inputs and market, either through support of the research organisation or by marketing the crops as a group.

The tricot trials were carried out by members of farmer research groups. This group aspect offered an incentive for the respondents to decide to participate in the trials.

5.4.3 Reasons for sustained participation

The decision to sustain participation is based on four factors: (1) seeing improvements in how the trials are carried out, (2) a general interest in participating in research processes, (3) staying part of the group, and (4) waiting for the results of the trials.

5.4.4 Reasons for 'dropping out' or discontinuing participation after initial participation

Reasons for deciding to discontinue participation are due to a lack of information on the benefits of the trials or when personal challenges prevent participation.

5.5 Discussion

Thematic analysis was used to answer the two overarching research questions guiding this study. Here I present the five main hurdles in the user experience of (potential) tricot users.

5.5.1 Recruitment process

One of the themes that emerged from this field study is the exclusive nature of the trials. The *tricot* approach's aim is to involve large numbers of farmers in research processes. In fact, if more people participate the results become more robust. Perhaps the fact that the organization was testing the approach, rather than scaling up their research efforts, caused them to start conservatively with a lower number of participants. A lack of confidence or unfamiliarity with a new approach could also be an underlying reason why the researchers were hesitant to share the results with the participants.

The recruitment of participants is left to implementing organizations, who might have a different agenda leading to altered recruitment criteria. For the *tricot* approach having a diverse population represented in the sample of participants is an important factor determining data quality. Similarly, the greater the number of participants, the better the results will be. Implementing organizations are tasked to distribute trial packages, collect data and serve as the 'front office' for participants. They are limited in terms of resources especially staff time. For implementing organizations it is important to have a manageable number of participants to be included in the trials. This might be one of the reasons that the organizations for the trials represented here, decided to group farmers together and use a single lead farmer as their representative and point-of-entry into the community.

Recruitment relying on self-organization within the farming communities makes it unlikely that selection takes place at random with some people more likely to get asked to participate than others. This seems like a missed opportunity of voluntariness for *tricot* implementation, not only in terms of the potentially selective nature of recruiting participants but also in terms of experiencing the consequences of non-compliance as part of participation. The ability to voluntarily contribute to research provides a strong experience of autonomy (and intrinsic motivation). However, this autonomy is reduced by attaching extrinsic motivators such as exclusion when participants are unable to attend meetings.

5.5.2 Lack of training or clear instructions

In the field study participants indicated that they did not receive enough information about the project. There were few touchpoints after the recruitment and training stages of the *tricot* research cycle and results were only provided to participants after harvest, not during the planting, observation, and data collection stages. There were few opportunities to communicate or share knowledge with researchers. As a result, engagement might drop during these stages and pick up again after interaction with field staff or the final workshop.

Several respondents indicated that they would have liked to receive more information during the onboarding stages of the research. Respondents felt they lacked some training in how to plant or how to fill the observation cards. The participants did not keep records of observations during the growing season. The fact that participants are not prompted to fill the data in the field at set times during the growing season, leaves quite a few 'openings' that allow participants or local facilitators to fill the data based on recollection rather than observation. This might compromise the data as participants now base their preference on the total performance rather than looking at individual traits. One of the interviewees mentions that the extension officer filled the form for her. Participants who received guidance on how to fill the form indicate that it is an easy process.

The fact that all respondents indicated that the forms were filled after harvest when the group met, indicates that data was based on recollection, rather than observation. This can be problematic for two reasons: first, making observations at the right times during the growing season prevents memory bias where the memory either positively or negatively affects the rankings of a particular variety compared to the other varieties in the trials. For example, germination rates might have been lower for variety A, however since harvest was higher for this variety, the poorer germination rate compared to the other varieties is quickly forgotten and a favourable ranking is provided for all its plant characteristics. Secondly, writing down all observations after harvest might seem tedious or a bit repetitive which could also negatively impact data quality.

5.5.3 Expectation management

Another theme that emerged from the data is a lack of information on the value of the tricot approach and what benefits it might bring to the participants. The high expectations that some of the participants held, were not attained in the 1-2 research cycles in which they participated. Participants had a wide range of expectations, varying from receiving seeds to knowledge gains and being part of a group, to the collective marketing of the crop or being contracted as seed producers for the research organization.

5.5.4 Feedback on the results

Tricot involves citizen scientists in their research. One major benefit for the participants of tricot is the fact that they do not need to grow 20-30 varieties themselves in order to find out more about their performance. They only have to grow three varieties and have the ability to learn about the performance of many varieties. Another benefit of the *tricot* approach for the participants is that they are able to conduct the experiments and learn by doing it themselves. They are able to plant the 'new' varieties on their own farms and test them for whatever characteristics they are interested in. So most of the learning takes place there, on the farm. And whatever happens in terms of data collection or feedback is probably of secondary importance to them. Participants were able to compare the results on their own trials with other farmers in the research group, however, they had not been informed which groundnut varieties ranked highest in the overall trial results. Respondents expressed interest in receiving the overall results of the trials. They did not receive feedback on the results of the trials and therefore were unable to compare their results with other groups, which as they indicated is a valuable outcome of participation.

5.5.5 Reciprocity

Tricot relies on the voluntary contributions of its participants. In return, researchers offer the participants a valuable learning experience. User interactions with the organization, with the research itself, and the wider community influence participants' motivations, for example, the perceived relationship with the organization. The research organization NARI has been working with farmers in the region since the 1970s. It is possible that other motivations driven by indirect benefits exist. For example, the reciprocity of participatory research where researchers rely on farmers to test their varieties in-situ and farmers rely on researchers to supply them with new crop varieties or knowledge. Or the fear of opting out which could lead to a higher chance of being excluded from any future participation in research (and the subsequent benefits). Even if this particular research doesn't offer the benefits that participants are expecting, other interactions or future research projects might. Therefore, maintaining a healthy relationship with the research organization and its representatives is seen as important for farmers interested in participating in research. Furthermore, agricultural researchers are seen as professionals who can teach farmers how to optimise their productivity. Any information or training they might bring, is better than no information. This is illustrated by the trust that several respondents indicated that the researchers will come back to share the results at a later stage, despite the fact that two cycles of tricot trials had already been completed. In fact, from the twelve people I interviewed only two respondents indicated that they were not interested in participating in the trials. Others who dropped out of the process indicated that personal challenges prevented them from regular participation and they were asked to leave. The willingness to participate is not an issue, however the ability to participate and benefit fully from what the approach is said to deliver, was not attained in this particular implementation.

5.6 Reflection on the design process

The main question here is 'what do designers need to know about people's needs to be able to innovate through design?' I borrow this question from Brouwer and Dorst (2014) who explore what information, and *how much* of this information is needed to be able to frame the design problem. This collection that constitutes the rich experience information presented in this chapter cannot be communicated as a set of facts. It is more a process of sense making and gaining understanding that I reflect on to show how such a designerly approach might work in practice. I chose to first present the reader with a combination of raw data and suggestive interpretations to be more authentic about how data collection as part of the design process took place. It also provides an opportunity to the reader to start their own process of sense making as they read through the chapter, without knowing beforehand which route I as the designer chose to take. The intention of this thesis is to show what a standard design process could look like when applied to participatory agricultural research design. The conclusions or summarising statements presented at the end of each section, represent just one possible route and do not represent an exhaustive list of the constraints and opportunities that *tricot* might bring.

Interviews allow the researchers to collect in-depth data around an experience. They are a quick and easy way to collect user experience data and identify the underlying reasons driving the motivation to participate and sustain participation during multiple research cycles. Individual interviews can also uncover more 'personal' insights: things that people would be more reluctant to share in a group setting. One-on-one interviews are better suited to solicit insights from a wide range of participants, for example, participants who would normally not be comfortable speaking up in a focus group discussion. However, it is important to realise that this will mostly capture explicit knowledge and it is difficult to get to a stage where tacit or latent knowledge is shared using user interviews (see figure 14). The prototyping field studies and farm visits presented in chapters 9 and 10 would be more useful for capturing information on participant behaviour and their knowledge.

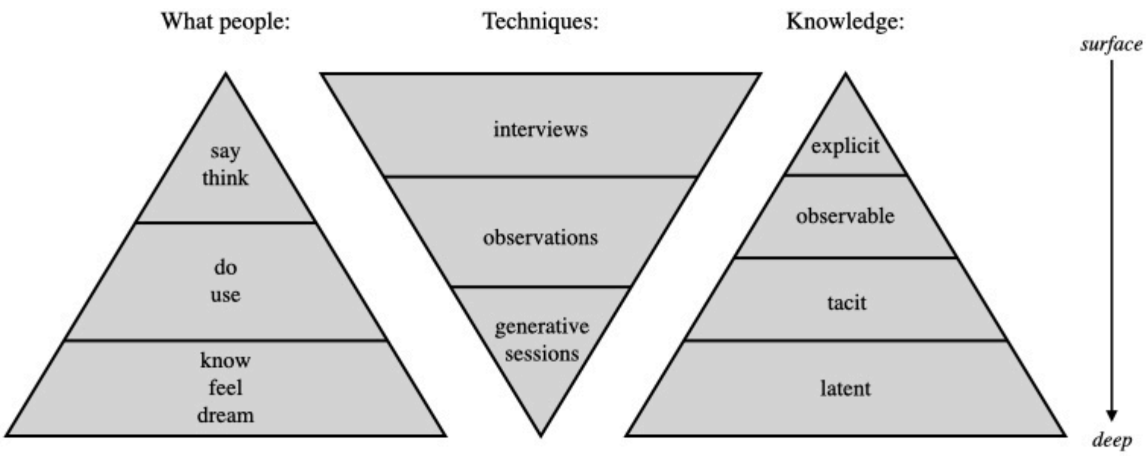


Figure 14: Techniques for accessing different levels of knowledge (Sleeswijk Visser et al., 2005)

5.7 Conclusions

With *tricot* being a citizen-science inspired agricultural research project, emphasis should lie on the accountability towards end users in providing learning outcomes for those participating. Much of these benefits rely on a close connection with agricultural extension or field staff involved in the implementation of the project. The ideology of the *tricot* approach in reaching a large number of participants and offering them non-monetary incentives for participating in crop variety evaluations underlies the current ‘citizen science’ approach. Additional organisations are contracted to carry out (part of) the activities. These implementing organisations might not be sufficiently incentives to invest time and resources towards delivering the results back to the participants. This signals a misalignment between the designer, the researcher and the implementers.

Besides feedback on the process, feedback on the results is another important prerequisite for engaging participants. Implementers should be held accountable for disseminating the results in an appropriate manner to its participants for ethical reasons as they are the ones who collected the data and for offering participants the benefits of the research. This to ensure real learning outcomes are offered to participants. As we’ve seen in the examples from this chapter, feedback provision on the results of the trials did not seem to be a major concern of the implementers. Perhaps there is a need to look at the institutional design of tricot in terms of who holds the responsibilities of disseminating the research results to individual participants, who designs the paper formats provided to each individual participant and who collects and analyses the data.

In the *tricot* approaches reported here, there seems to be a lack of touchpoints throughout the research cycle. Communication is limited to the start when the implementing organisation are training farmers on how to conduct the research and at the end when (if!) They share the results of the trials. And even in these two brief interactions, the quality of the communication is open for optimisation. This seems extractive and might seem to outsiders as if the researchers are mainly concerned with collecting data from the farmers (“keeping bees to collect the honey, but fail to return the hive”). A more engaging process could solve some of the issues reported here. Tricot projects will differ in how they set up their implementation structure, however tricot makes limited provisions for upstream information flows other than collecting farmers data based on the observation cards. Bioversity has piloted ‘Ushauri’ , an automated information service where farmers can log their questions into an online platform using their mobile phones and feedback is provided by extension officers and other experts at a convenient time. This pilot took place at the same time as field research took place. However it fell outside the scope of this research to take these additional touch points into account for the user journey. The results of the experiment can be read in Ortiz-Crespo *et al*. (2020).

Whilst there is no doubt that participants value the fact that they are able to conduct their own trials using seeds provided by the research organization, I identified several pain points in the user journey that might influence participants' ability to fully benefit from the approach. Recruitment relying on self-organization and a lack of communication and expectation management are factors in the design and implementation of *tricot* research that might influence the user experience throughout the whole research cycle. What is driving participation is not only the ability to conduct experimental trials autonomously but also the relationship with the research organization or the farmer research group. In this particular implementation of the *tricot* approach, the implementation didn't follow the guidelines as suggested by the developers of the approach. This revealed several contextual and implicit factors forming barriers to the experience of users, which otherwise might have been considered to be indirect effects falling outside the scope of the user experience and therefore not being part of the problem space. A small sample of twelve respondents were included in this field study, yet a rich picture of the user experience was compiled in this chapter. There is no need to invest heavily into baseline studies at this stage, as it is meant to explore the problem space before we design solutions or experiments to test solutions. This is different from a typical research design process where first the problem statement is made, followed by background research and hypothesis formulation. Conducting user interviews early in the process, therefore, helped to increase the understanding of the barriers to participation to a level which studying secondary research, would not be able to achieve. Also talking to real people and hearing about their specific situations is a more fun and rewarding process than simply asking them superficial questions about whether they 'liked' the approach or what could be improved in a subsequent research cycle.

Chapter 6

Design synthesis

6.1 Introduction

Design synthesis is perhaps the least visible part of the design process. The process of decision making (converging / prioritising what to focus on) after presenting research findings and bringing experiences and even hunches to the table in a messy abundance of data, is sometimes referred to as 'the magic of design' (Kolko, 2011), mostly because this process takes place within a person's individual sense-making process or through collective analysis. There is no standard process of 'doing synthesis' and often the process occurs implicitly through individual sense-making (e.g. Taking in all the information) and acting on 'hunches'. This process is rarely documented. Here I experiment with different synthesis methods:

a. By modelling data using different representations borrowed from other designers.
b. Through experimenting with different activities to demarcate the problem space.
c. To go through a process similar to grounded theory to converge all the information into a set of design recommendations.

This chapter took longer to put together than others, perhaps the "magic" wasn't instant nor a straightforward process as I gained inspiration from the literature and experimented with different forms of synthesizing. This chapter shows the activities that informed the design process as it happened in 2018, and much of the diversions or analysis conducted at a later stage were left out as they did not inform the different stages of the design process and could be seen as an act of dressing up the data (figure 15).

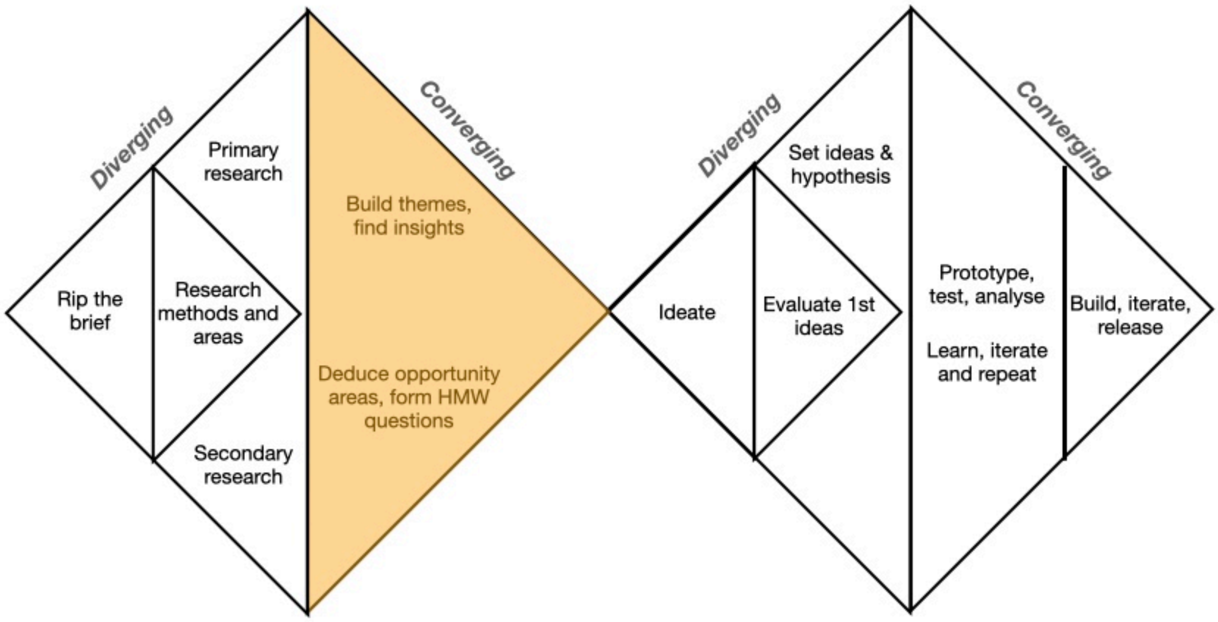


Figure 15: Stage 3 in the design process

The first step of the synthesis process is intended to compile knowledge to describe the *current state* of tricot trials in terms of their implementation and design. The current state is made up of parts of context (e.g. Target environment), the application domain, intended users and their tasks, and the specific benefits and activities the service (tricot) provides. We follow a series of steps that provide insights into the user journey by modeling the data. Different methods are used and layered into a customer journey map of the experience of participation. Using these different methods in parallel allowed me to gain experience and learn which methods provide the best representation of the current state. Here we try out different alignment diagrams to turn observations and findings into 'actionable' insights (Kalbach, 2015). These diagrams are meant to spark a conversation by visualizing the data rather than presenting analyzed data and findings as facts that the intended audience needs to digest. The diagrams are helpful in creating empathy, for example by showing the research process from the viewpoint of the user or to create a common picture of the process. They can be used to reduce complexity, bring together multiple strands of information and highlight opportunities (Kalbach, 2015). Because much thought and effort usually goes into creating the diagrams in terms of their visual aspects, readability and self-evidence they also tend to have a longer lifespan than findings in a report.

The second step of the synthesis process is aimed at converging data and design knowledge by highlighting the main take-aways from the analysis, finding insights and demarcating the areas where design opportunities lie. The findings presented in the previous section together with experiences and more subjective insights or 'hunches' inform the process of problem finding. The problem area can be delineated by asking who is affected and in what way they are affected. We look at the motivators and what potentially demotivates participants in the tricot research process. Based on this we list a series of design recommendations and how-might-we questions to provide the impetus for the ideation and prototyping phase of the design process.

The demarcated area can be referred to as a description of the future state. The future state or end state is how we envision the outcome of the design process to be. Rather than designing for optimizing the current state by envisioning the ideal state, we take a step back and assess which features of tricot we would like to retain and which features we would like to add. This then forms the basis of the ideation process which will be presented in the next chapter.

6.2 Methods

First, I start with an *activity chain analysis* that lists all the different steps users have to undergo as part of their participation in tricot trials. Every interaction here is important as it might impact the user experience or any of the subsequent steps in the user journey. I then compile *activity profiles* that analyze each step in the research process further by listing the motivators and hurdles for different actors, describing the needs of the user and the 'system owner' or the initiator of the research. The method of compiling activity profiles is derived from Deterding (2015). He uses behaviour chain analysis to deconstruct complex activities into 'action chains' and associated behaviour of different actors. I use it here to break down each step in the research process and highlight potential differences between what the user finds motivating and what the initiator of the research aims to achieve. Activity profiles are used to break down high-level activities into actions, needs, motivators and hurdles. This might bring insights into the salient features underlying participant motivation and whether they are aligned with what the researchers or developers of the approach intended.

I also compile a *service blueprint* of the research cycle. This diagram shows the range of interactions, triggers and touchpoints, as well as the motivations, frustrations and meanings that we can leverage and improve during the further design process. This includes the steps in the research process that do not involve the user directly, for example, the preparatory steps and the design stages where researchers make decisions on a range of different aspects or which technologies to include in the trials, how many trials they aim to set up and who to involve in the research process.

Last I modelled the data into an experience map visualising the general user behaviour in the different research phases. Here I compiled the information from the activity chain analysis, activity profiles and service blueprint into one visual representation of the user journey. I added layers in terms of the motivation of participants and visualised where in the user journey thoughts and feelings of users were positively or negatively affected. A narrative explains the process further. I also added 'process' layers describing how the approach is implemented. For example, who are the actors involved, where does this phase take place and which mode of communication is used? See section 6.3.4 for an overview of all the elements included in the experience map. In the discussion I indicate how the user journey diagram informed the design process and in the reflection section I review how the creation of this particular diagram came together and dsicuss how the process could be improved.

6.3 Modelling data

6.3.1 Activity chain analysis

We uncovered the individual actions participants need to undertake in the *tricot* research process in a activity chain:

> Get contacted & learn about tricot > get invited to the initial workshop > the initial workshop > hear about the value proposition of participating in the trial > decide to participate > registration of a trial package > receive a trial package > listen to planting instructions > find a suitable piece of land > prepare land > plant three different crops next to each other > plan to go to field to observe crop > take observation card and pencil to the field > observe the three varieties for different

characteristics at set intervals > fill observation card (for each interval and each trait) > evaluate and compare the crops for the final data entry > wait for data collector to visit farm or to call > hand over results > wait to get contacted > get invited to a final workshop > join final workshop > receive feedback on the results of the trial > ask questions > discuss with other participants > provide customer feedback / evaluate the trial > decide to participate in a next cycle of tricot.

These activities are more than the sum of all parts, meaning that one 'step' in the tricot research process likely encompasses multiple actions from the user. Tricot users have to prepare the field before they can plant the seeds and have to weed and maintain the crop before being able to make observations. The activity chain shows the cost of participation for the users in terms of labour input or time spent. This information might help to rethink the research process from a more user-centred perspective in contrast to the more researcher-centric perspective described in the tricot guidelines (van Etten *et al*., 2020).

The activity chain shows the most optimal route to complete tricot trials. This further cements the idea that the steps in the research process might not necessarily lead to the envisioned *ideal state* of implementing tricot trials. Tricot trials are presented as simple research experiments with easy to follow instructions. Alternative interpretations on how to fulfil the different tasks have not been considered in the design even though they might lead to outcomes as we saw in the previous chapter. For example, when participants are excluded from further participation after not being able to join meetings:

Get contacted & learn about tricot > get invited to the initial workshop > **fail to attend the initial workshop** > **being excluded from further participation**.

This in itself can cause a selection bias. Another example is when participants are for any which reason insufficiently motivated to make observations in the field at set intervals:

Get contacted & learn about tricot > get invited to the initial workshop > the initial workshop> hear about the value proposition of participating in the trial > decide to participate > registration of a trial package > receive a trial package > listen to planting instructions > find a suitable piece of land > prepare land > plant three different crops next to each other > plan to go to field to observe crop > take observation card and pencil to the field > observe the three varieties for different characteristics at set intervals > fill observation card (for each interval and each trait) > evaluate and compare the crops for the final data entry > wait for data collector to visit farm or to call > **receive instructions on how to fill the observation card > fill in the observation card after harvest** > hand over results > wait to get contacted > get invited to a final workshop > join final workshop > receive feedback on the results of the trial > ask questions > discuss with other participants > provide customer feedback / evaluate the trial > decide to participate in a next cycle of tricot.

Legend:

Unexpected or added activity

Activity not carried out

In this example the outcome may seem the same, however the data collected is different from the intended data as it is based on recollection as opposed to observation. For tricot users their recollection of the early performance characteristics (germination rates, pest or disease infestations) of varieties could be biased after seeing the full performance at the end.

Part of the ideology of citizen science/tricot trials is that participants should be able to complete the tricot trials under their own management and under real conditions (van Etten *et al*., 2020a). However, ideally each individual process should have the same outcome and generate quality data.

6.3.2 Activity profiles

We compiled activity profiles for each of the steps in the tricot user journey. See figure 16.

Activity	Recruitment
Research step	Step 3: Recruitment
System owner goal	Many motivated participants
Metric	Number of participants in the initial workshop

User need	Get more information about the tricot project
Actions	Get contacted > Receive information > Decide to join initial meeting
Motivators	Curiosity in new technologies, ‘Being asked’
Hurdles	Not being asked, incomplete or unclear information, limited number of participants
Activity	Registration
Research step	Step 4: Distribution
System owner goal	Distribute as many trial packages as possible
Metric	Number of trial packages distributed
User need	Receive a trial package
Actions	Join initial workshop > decide to participate > provide personal details > receive trial package
Motivators	Curiosity, receiving seeds (or technologies) for testing
Hurdles	Location or timing of the initial workshop. Unclear information.
Activity	Training
Research step	Step 4: Distribution
System owner goal	Motivate participants to collect quality data
Metric	Number of training sessions
User need	Receive agronomic advice, interact with researchers, understand the tricot process
Actions	Join training session > interact with researchers > learn about requirements > decide to participate
Motivators	Learning, collaborative (see who is else joining)
Hurdles	Perceived resource-intensity, lack of self-efficacy

Activity	Planting
Research step	Step 5: Execution
System owner goal	Technologies planted in rows next to each other
Metric	Number of planted trials
User need	Technology testing

Actions	Find suitable land > prepare land > wait for favourable weather conditions > open trial package > find thee packets of seeds > plant seeds in rows > label rows with code of corresponding packet > wait for germination
Motivators	Curiosity to see crop germinate, anticipating yields, experience of planting new crops/varieties
Hurdles	Unfavourable weather conditions, receiving wrong seed types or poor quality, difficulty of contacting researchers to get new seeds, not receiving seeds on time
Activity	Observing
Research step	Step 6: Observation
System owner goal	Participants collect their own observational data in written form using the prescribed template
Metric	Number of engaged farmers (unmeasurable??)
User need	Good seed performance
Actions	Crop germination > go to field > make observations > repeat making observations
Motivators	Curiosity to see germination, reference and learning about new technologies
Hurdles	Weather conditions, poor performance of crop
Activity	Fill data
Research step	Step 6: Observation
System owner goal	Data collection
Metric	Number of observation cards filled using observational data
User need	Comply with the requirements of participation
Actions	Go to field > observe > make comparisons between three crops > fill the observation cards
Motivators	Learning about technologies, curiosity
Hurdles	Physical location of observation card, poor performance of crop, poor understanding of observation questions
Activity	Data collection
Research step	Step 7: Compilation

System owner goal	Collect quality data
Metric	Number of data points collected
User need	Hand over data to be eligible to receive results / to finalise trials
Actions	Data collector visits farm / contacts farmer > participant provides feedback (answers on the observation card) > data collector informs participants of rest of process (doesn't always happen)
Motivators	Interaction with program staff, being part of something bigger, sense of completion of tricot
Hurdles	Not knowing when data is going to be collected, not being available at time of visit
Activity	Results
Research step	Step 9: Feedback
System owner goal	Knowledge sharing, ethical thing to do
Metric	Number of information sheets distributed / workshops organised
User need	Receive information about the performance of all the technologies other participants used, compare results with others
Actions	Decide to join the final workshop > meet with researchers, program staff and other participants > share results > receive information sheets
Motivators	Expectation, sharing results and comparing success (rate how well they did)
Hurdles	Timing and location of workshop, perceived failure of own trial, unorganised workshop
Activity	Evaluation
Research step	Step 10: Evaluation
System owner goal	Evaluation of tricot cycle and guidance on how to improve a next cycle. Potential of retention.
Metric	Number of participants willing to participate in next cycle (retention)
User need	Improving the tricot experiment, making it more useful for them
Actions	Decide to join the final workshop > meet with researchers, program staff and other participants > evaluate how trials went (share experiences) > provide feedback
Motivators	Having a voice and sharing their experiences (being more than just a number on a sheet).

Hurdles	Dissatisfaction with the process, not being heard, lack of participation in the workshops

Figure 16: Activity profiles for tricot research trials

Whilst the motivators and hurdles listed here were already known (see chapter 5), compiling the activity profiles helps to digest and present this data in a concise manner. It is much easier to read to a profile than it is to read through multiple user interviews.

The activity profiles also highlight the potential friction between the goals of the system owner/researchers and the goals of the user/participant. For example, for the profile on *recruitment* the researchers aim is to recruit as many participants as possible with little resources.

> The tricot trial format is very simple for participating farmers: each executes the mini-task of evaluating only three technology options, out of a range to be tested. This makes it possible to engage many farmers without expending excessive effort on training or supervising them (van Etten *et al*., 2020a).

Users need to receive sufficient information on the tricot approach and possibly a demonstration on how to set up tricot trials. When little resources devoted to recruitment this might lead to participants have insufficient information on the requirements for full participation. This might lead participants to decline participants or if they decide to participate to have unrealistic expectations or understanding of the research process surrounding the trials.

Compiling the activity profiles helped us identify potential misalignment between different actors in the approach. Two potential alignment issues are signalled here: the balance between resources invested in return to collect quality data from farmers and the accountability of the system owner (initiator) towards the end user after the data has been collected.

6.3.3 Service blueprint

We visualised each of the steps in the research cycle of tricot. We had not previously included the steps necessary to design and complete a full research cycle and needed to draw a visual map of the full tricot journey for all actors involved (see figure 17).

Figure 17: Service blueprint for the tricot research process

This service journey shows that the inputs from the researchers are mostly situated at the beginning of the research process and after the trials have been harvested. The steps in the research cycle where participants conduct the actual trials do not include any touchpoints with the research organisation or local facilitators. From an autonomy perspective this might work, as the ideology behind tricot depicts that participants should be able to carry out their own trials under their own management. However, without communication throughout the research cycle or progress feedback, it might also lead to detachment of the participants. And as such could negatively impact peoples' engagement.

The service journey further visualises where the potential misalignment signalled in the activity profiles is situated. For example, after the harvest the researchers have collected all the data from the participants. Other than providing the results of the analysed data back to participants due to ethical considerations, there are no other incentives to hold researchers or local facilitators accountable for doing so. Furthermore, in our field study we also noticed that participants have low expectations in regards of researchers bringing back the results and therefore it is unlikely that they would ask for the results.

6.3.4 User journey diagram

Using the data from the field studies presented in the previous chapters, I compile a user experience map visualising the pain points and user journey of *tricot*. The information from the user journey and the behaviour chain analysis are brought together in a user experience map. This visualisation serves two purposes: (1) the process of compiling a user journey map forces me to look at the research process through the lens of the user and (2) it brings together fragmented information and an ability to communicate this understanding clearly / visually to others. Visualisation of the process a user goes through when (s)he is interacting with a product or a service, is a common tool in product design. More recently journey mapping has also been used as a tool to achieve behaviour change, mostly in the public health sector (Silvert and Sanagorski Warner, 2019). I did not find any records of journey mapping applied to consider the design of agricultural research processes. The nearest equivalent would be mapping and visualisations of value chain research (GSMA, 2017).

We used the information from the blueprint as a base to compile the user journey diagram. The *process* layer shows the direction of the actions, for example when it requires another actor to take initiative (incoming), if the user is responsible for taking action (internal) or whether the user is responsible for communicating with another actor (outgoing). The *actions* layer describes the decisions the user makes at each research stage on fulfilling the activities of the trials. The *activity* layer shows the interaction that takes place between the user and the research implementation. Based on the user interviews I was able to distil some of the *thoughts* users might have in relation to the activities and expectations for each of the research stages. The *feelings* layer translate these thoughts into positive and negative epistemic emotions (Arango-Muñoz, 2014). These epistemic labels help clarify positive and negative action and behaviour patterns of users which we can utilise as design knowledge. A line shows whether the thoughts and feelings of users are predominantly positive or negative. This overall positivity or negativity 'rate' of users were drawn from experience (arbitrarily). The *touchpoints* refer to modes of communication: for example face-to-face interactions, mobile phone or app (registration) and interaction with the data collection format (paper). The *form of interaction* describes the activity setting, for example, group meetings or individual activity and the *location* within the community where the interaction takes place. The *duration of the stage* provides an indication of the time users spend in each research stage. The last layer indicates which actors might be involved at each research stage.

The user journey diagram provides insights into the experiences of a participant of a tricot trial, starting with the decision to participate and all the subsequent steps that they need to complete the research (see figure 18). This user journey is based on an example of Kalbach (Kalbach, 2015:7). This is a fictitious scenario (fictitious but based on real data from *tricot* users) that describes the experience of participating in *tricot* trials.

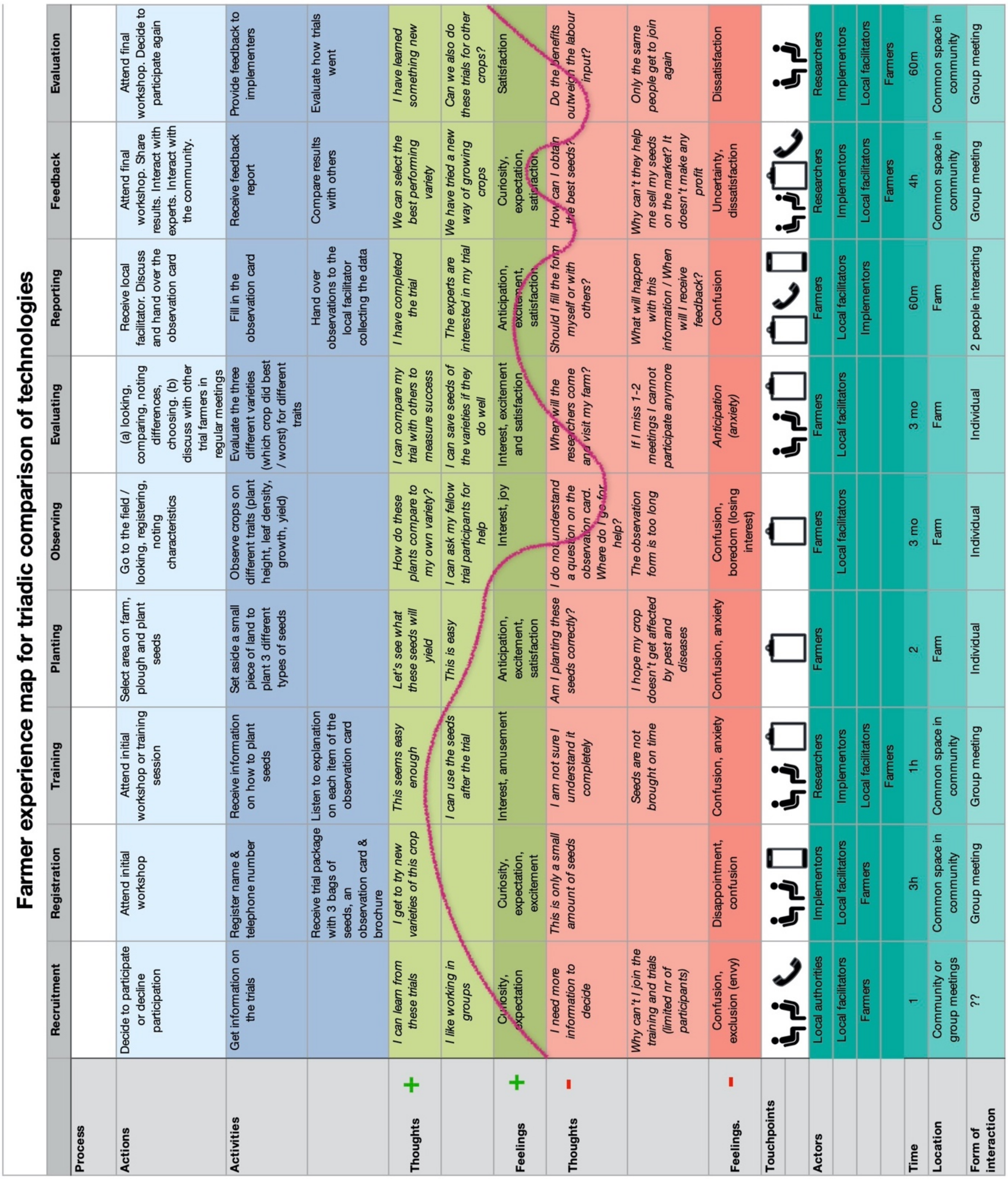


Figure 18: User journey visualisation of tricot trials

This user journey diagram visualises the fluctuation in epistemic emotions for each of the research stages. The dip during the planting and observations stages shows that the communication might be insufficient or inconsistent throughout the different touchpoints in terms of interactions of the research organisation or local facilitators with participants. This helps to explain why as an experience the tricot trials might fall short of the expectations that the participants have at the beginning of the trials. Participants will experience positive and negative feelings throughout the research cycle. A short narrative that talks us through the epistemic emotions might help clarify this further:

> Anticipation builds up from the moment of recruitment to the initial workshop. People are looking for information on how the trials are organised and what benefits it can bring. During the initial workshop they receive a trial package yet they do not know which varieties they are testing: this could lead to excitement (I wonder how these seeds will perform), but also to confusion or even anxiety if they do not know exactly what is expected from them. Participants are mostly smallholder farmers who are experienced in planting and growing crops. Therefore the trials in itself might not be very exciting from a novelty perspective, yet the anticipated outcomes in terms of knowledge gains will be (e.g. Learning about the performance of new varieties or crops they have little experience with). After the initial planting stage, there is not much interaction between the participants and the local facilitators or researchers. This might lower the interest in observing the trials especially if the participants are not sufficiently incentivised to observe and record data. Anticipation builds up again after harvesting the trials. Participants are expecting a visit of the local facilitators to collect the data. Data collection validates the user experience and should be seen as a 'big deal' in the research process. At this stage participants may not be fully aware of the next steps in the research process in terms of what benefits they will receive after the trials or how to assess if their trial was a success was in comparison with other participants. For example, participants might expect help with marketing the produce or expect provision of seeds or other handouts. Will they have a chance to interact with researchers if they decide to visit the trials? What sort of feedback on the results can they expect? A lack of expectation management at this stage could lead to uncertainty or dissatisfaction when the expectations aren't met. During the final workshop participants will probably feel a sense of achievement as they successfully completed their trials and can now share their knowledge with others. When feedback on the results is shared back to the participants they know which varieties perform better than others. In case this information provision is not satisfactory, and this can lead to disappointment. However this depends on the individual expectations and expectation management from the implementing organisation. Rumours about expected hand-outs spread easily within a community, and can also affect the level of satisfaction of the trial. During the final stage of the tricot research process participants discuss how to improve the process with the implementing organisation. They can indicate if they wish to participate in a subsequent cycle of tricot. Experience shows that most participants are positive and wish to participate again. Participants are also interested in adopting the approach for different crops.

6.3.5 Pain points in the user journey

Pain points represent the challenges people experience when carrying out the tricot trials or when they are interacting with field staff or researchers. From the findings and the modelled data presented in previous section, I distilled the following pain points in the user journey.

Recruitment stage

Recruitment processes are often outsourced to implementing organisations as they are the ones with ties to the community. It is important to realise that organisations might have a different agenda from the researchers. For example, researchers want to involve many participants into their research so they have access to many data points. Implementing organisations need a manageable number of participants and efficiency in touch points as every 'moment of contact' costs them money. The question then arises of who is most likely to participate in *tricot*. Is it users that already have linkages with the implementing organisation or does it attract a new pool of participants who are interested in participating in agricultural trials and never had the opportunity to do so before?

Registration

Participants might feel uneasy about providing personal data to unknown researchers. There might be some uncertainty about how the information they provided is used. Furthermore, participants might not be completely aware what they are subscribing to as no consent has been taken. They sign up voluntarily, but are the benefits and responsibilities completely clear to the participants? Experience shows they only receive an oral orally instruction or explanation of the research process in a group workshop. They might not hear all the information they need to know or might be reluctant to ask for clarifications if they do not understand something. And if any issues aren't clarified beforehand, do they indeed consent to all?

Training stage

All information regarding the *tricot* process, its benefits and responsibilities as well as the technical knowledge needed to plant the trials are communicated to participants in a single workshop before the start of the trials. There is a overload of information for participants at the beginning of the research process with almost no information coming in after the research has started. The implementing organisation relies on these single workshops to relay all the information that participants need to complete the trials. The observation card offers only a limited amount of information to guide them through the process and only if participants keep the observation card at hand for the duration of the growing season. For an experimental trial that requires its participants to undertake several steps over the course of an entire growing season, it would probably be better to incorporate triggers or reminders into the research process.

Planting stage

Participants might still have questions related to how to plant the trials in terms of spacing, method of seeding or planting techniques. Not knowing what to do when planting the trials can lead some to worry about their ability to fulfil the responsibilities of the trial. Furthermore, participants might not be certain where to go to for reassurance the trials have been planted in the right way. Participants might be unsure about the validity of their questions. Or their questions might not be answered in a satisfactory manner as field staff may not have all the answers themselves.

Participants have to decide how much effort they will put in the trials. The tricot trials are kept to a small size purposely as a smaller size means they are easier to manage and easier to incorporate in participants' farms. However, this could lead some participants to question whether it is worth the efforts or the inputs in terms of fertilisers and pesticides as the harvest will also be small. Participants might opt to neglect the trials in favour of their normal production which is more likely bring a higher return on investment. In this situation can we still say the trails were carried out 'under normal management' or is the data on the performance of the crops likely tainted?

Observation stage

A lack of communication during the observation stage of the project can hinder the data collection process if participants lose interest or forget to go to the fields to make observations based on the traits in the observation cards.

Observation cards are physically handed to the participants together with the trial package. Participants need to find a way to safeguard the piece of paper in their houses and not forget where they had put it. They are then required to take the card to the field at specific timings in the plant growth stages or research cycle, most likely without being nudged to do so. Standing in the field to make observations and subsequently filling data on a piece of paper is a small challenge in itself. Participants are more likely to fill the observation card at a later stage when they are at home, if they remember to do so or feel responsible enough to do so. It can be expected that observation cards are filled after being asked to do so by local facilitators based on recollection rather than observation. Furthermore, due to the nature of certain farmer groups working together in completing the trials it is also understandable that participants opt to fill the cards together when they are discussing this topic in one of their meetings. This might lead to a 'free-rider' phenomenon which is precisely what *tricot* is trying to address (Misiko, 2013; van Etten *et al.*, 2016).

Data collection stage

Not knowing when and in what form results will be shared back to them, can have a demotivating effect on participants. Participants have to wait some time after they harvested the crops and handed over their data to receive a invitation to a workshop. How are they able to purchase or receive the seeds of the varieties that they preferred over their own local variety in the trials? They might decide to opt out at this stage and forget about the results altogether. Participants with experience in participatory agricultural research might have lowered their expectations in receiving feedback on their participation as it is not uncommon for researchers to forgo sharing the results of the experiments to their participants.

Sharing results stage

Receiving an invitation to a final workshop might in turn raise expectations and speculation about what will occur during the event and if there are any more benefits to expect. Or on the contrary, there might be a lack of interest in spending more time on the project as participants already completed all their tasks. Participants were already able to decide for themselves which varieties they preferred as they were experiencing the varieties first hand in their own farms. Overall uncertainty about what the event entails might lead to either inflated expectations or a general disinterest or skepticism on the results.

When expectations are set too high, this can lead to disappointment. For example, participants who expected to have the opportunity to obtain larger quantities of their preferred seed might feel duped when they find out the seed is not available.

If the results are disseminated in a group workshop, then this allows for the communication of generalised results only. The individual results are provided on a piece of paper called the 'information sheet' which is explained by local facilitators during the workshop. It is uncertain that the local facilitators received training on how to communicate these results or how to attribute meaning to it. Participants might not see the relevance of the results for their own situation as they are not sure how other farmers planted or what management practices they used. They are not able to see and compare the different varieties through observation (in real life) after the trials. The information sheet presents the data in a few graphics and numbers and participants might lack the confidence or the ability to interpret the results themselves. Implementation organisations receive a training from researchers on how to compile the data and obtain the results of the trial using the climmob platform, however they are not provided with a manual or template on how to facilitate the final workshops and get participants to interpret the results as a group. Or how they can offer instructions to local facilitators or participants in how to read the results from the information sheet.

6.3.6 Summary

Taking a step-by-step process in visualising the user journey of a tricot participant helped to analyse and make sense of more than only the findings of the interviews. In addition I was able to rely on existing literature describing the methodology and ideology of the approach (van Etten *et al.*, 2020a,b) and my previous experiences in participatory agricultural research, to create different data representations. In this section, I described the user experience and visualised the user journey, first by diverging (expanding) the information and then by converging all the information into themes and pain points for each of the different research stages. In the next step of the synthesis process, I demarcate the problem space and identify opportunity areas for the continued design process.

6.4 Demarcating the 'problem space'

We use a field study as an exemplary model for the design of our prototypes, realising that other implementations of tricot might result in a different 'current state', In this section, we delineate the problem space and identify design opportunities.

The problem space 'hangs' somewhere in-between the defining and the developing phase of the double diamond model (see figure 15). It constitutes the gap between the current state and the desired end state of the design process. The desired end state should not be confused with the ideal state which will only occur in a situation where there are zero constraints. Especially in the design of services and in our case a research process, there are many factors influencing experiences users might have. By demarcating the problem space, it becomes clearer which problem the design process could solve and allows us to bring more than one solution to the table. In an ideal state, all 'problems' or issues would be tackled. Here we can prioritise the preferred outcomes of an ideal state from both the perspective of the researcher and the participant.

The ideal state for the initiators (researchers or implementers) of a tricot research trial:

1. Participants perceive tricot as simple and beneficial, this lowers the barriers of participation and leads to greater inclusion.
2. Participants are motivated and engaged throughout the entire research cycle and share non-biased and accurate data on the performance of different technologies (crop varieties).
3. Participants want to sustain their participation in another research cycle.
4. Researchers can complete a large number trials which provides access to data to discover trends in preferences and performance of a collection of different technologies. This takes up less resources than standard multi-location trials.
5. Participating farmers and their communities gain access to a range of options in terms of different crop varieties or technologies. Which increases their ability to adapt to climate change.
6. Scientists and research organisations accept the tricot methodology as a solid example of citizen science in agricultural research.
7. The method is implemented by other organisations who share their data to the

climmob platform.

The ideal state for the participants of tricot research is when the following benefits have been attained:

1. Access to seeds for experimentation and multiplication.
2. Trusted information on the performance of different crop varieties.
3. Being able to access a higher diversity of crop varieties (more choice) within their own communities.
4. Trying out new crop varieties in a low-risk manner. They don't have to buy seeds for experimentation.
5. Gaining social recognition as a tricot participant. They could become a seed distributor or provide agronomic advise based on their gained knowledge and skills.
6. Feeling a sense of relatedness through interactions with experts and their community.
7. Gaining formal experimentation and basic research skills.
8. Gain additional learning opportunities in terms improved cultivation practices, experimentation skills or pest and disease identification.
9. Enjoyment of utilising their expertise and skills to contribute to science.

These are completely different. This illustrates the advantage of being able to shift perspectives between researchers and participants.

The desired end state is:

A sufficient number of participants are motivated to collect and share their data And stay engaged throughout the whole research process. They have clear expectations on what to expect by participating in the tricot approach and these expectations are met. Therefore they want to sustain their participation.

The problem space can be further delineated by asking why participants are not fully engaged throughout the process. For example 'what are the unmet needs of the users, i.e. The participants?' Or 'how can we make the *tricot* approach more engaging for its participants?'. The answers are based on the field study presented in the previous sections:

1. **Why are participants not fully engaged throughout the whole research cycle?** → participants might not be fully aware of what is expected from them during the different stages in the research process.
2. **Why do some stages in the research process lack interaction?** → individual planting and observing are based on do-it-yourself principles and little communication takes place during these stages.
3. **Why don't participants interact more with field staff or researchers to ask for help?** → participants might not be able to directly contact researchers and contacting them through local facilitators might impede the response. Often local facilitators are not available full time to answer questions from participants.
4. **Why don't participants fill the observation cards in the field but later based on recollection?** → participants do not always carry their card around and when they do notice something interesting for data collection, they would have to go back to their house to get it. The field might be far away from the house or its inconvenient to carry a piece of paper and pencil to the field to make observations. It makes more sense to 'note it down later' upon returning back to the house. However, they might not immediately rush back to fill the form and therefore they might also forget.
5. **Why do participants have limited interest in the overall results of the trials?** → the results of the trials are not provided to them. If results would be provided, it would also have to come with clear instructions on how to interpret the data or how to make use of the results. Likely the most relevant information from the tricot trials is their own experience with the crops. How their results compare to those of other farmers is of secondary importance.
6. **Why do researchers not put more effort into providing meaningful data?** → it is unclear who is responsible for creating appropriate forms of feedback. Implementers might feel too little accountability towards the end user or lack the incentives to digest and present feedback on the results to the end user. Or they might lack the resources to do so. For both researchers and implementers the pay-off happens at the moment they collect the data from the user. Researchers are not rewarded for dissemination of research results to users (they are rewarded for publications), and researchers may not have the communication skills needed, while implementers do not have time or resources to obtain the results and 'translate' research results into digestible information for farmers.

7. **Why does it matter?** → to be able to deliver clearly defined benefits and learning outcomes to users and motivate participants to sustain their participation, researchers and implementers need to be accountable towards all stakeholders, including participants. This is one of the premises of citizen science.

There might be a potential misalignment between user needs and researcher needs. For example the importance of participant selection should not be overlooked. In the field study it was evident that recruitment of participants was selective, potentially leading to the exclusion of user sub-groups. Particularly for research trials which aim to represent insights into the varietal preferences of a diverse group of users, it is important to consider how to attract and involve a heterogenous group of participants into the research process. One of the design features of tricot is to make participation easy and attractive for its users. By keeping trial sizes small and collect data which is easy to measure by non-scientists, the designers of the research approach hope to attract (and being able to manage) larger numbers of farmers into their research than is possible with more traditional forms of participatory agricultural research. To deliver on these design features it must be clear what benefits the approach offers for its participants, for example how their data is being used by researchers and what they can expect in return of collecting the data.

The recruitment process ascertains the voluntariness of participants' contributions. In our case, participants' reasons for participation might be influenced by the existing relationship with the organisation or social pressure from peers. What was unsure was what would happen if participants based their decisions to participate solely on what they perceive to benefit from it/direct benefits. Would they still be as interested in participation? Particularly considering the benefits are not clearly presented to them before they start the research, nor did all of the benefit materialise for them (e.g. Lack of feedback of the results).

In the current tricot approach asking for consent is implicitly built into the process when participants 'sign up' or register using the mobile app. In the field study (and from experience) the mobile app was not used to register participants and it was not clear how consent was taken. Adding a process of obtaining explicit and written informed consent can serve as an important step towards increased accountability of implementers. It might also prove to be a indispensable step in any research process taking into account recent data protection regulations which have been put into motion in many countries around the world. Several other benefits come with a clear value proposition beforehand: increase understanding of the process, more 'voluntary' contributions and enhanced learning. Providing participants with a clear value proposition before the start of the research, will ensure that the benefits are communicated beforehand and that participants can base their decision to participate on the return-on-investment bases. Furthermore, presenting the value proposition in terms of how this data will help the individual participant; "I evaluate 3 varieties but get to learn about the performance of 20 other varieties in the process by contributing my data to the larger pool of data" e.g. The wisdom of the crowd principle (Surowiecki, 2005), might positively influence participants' willingness to collect quality data. Ensuring that participants know the purpose of the research beforehand, how their contributions are used and what they will receive in return will establish trust and accountability.

Tricot is designed to be a individual activity and participants indicate that they favour the autonomy of evaluation crop varieties on their own farms over group evaluations on demonstration farms. This is a strong benefit of the tricot approach. It also facilitates the participation of large numbers of participants especially when resources to train participants and interactions throughout the research process are kept to a minimum. But how can we keep participants engaged in the process if researchers and/or implementers are not there to offer constant support? Citizen science offers a alternative to traditional participatory approaches in engaging farmers into research by offering clearly defined learning outcomes that probably especially the research-minded farmers will be interested in. To be able to deliver on this citizen science prerequisite, designers of the approach should ensure that the language and information is appropriate for participants, especially for participants who do not use written forms of instructions or data collection on a daily basis.

6.5 Design recommendations

The question is how do participants stay engaged in the *research* aspects of the project if they are left to do the experiment themselves without much interaction with other participants or field staff? Whilst a clear benefit of the tricot approach is its autonomy in setting up your own experiment, it has not included specific measures to play into the competence of participants, e.g. Providing a feeling of mastery or that you are making progress. Interactions throughout the research cycle are limited to providing a instruction in a single workshop before the start of the trial and a final workshop to share the results of the trials. In the field study I presented earlier, the final workshop did not take place at all. This limits the interactions participants have with the research organisation to two occasions.

This increases the efficiency of the research process, however there is a clear trade off in terms of engaging participants into research processes and making it intrinsically motivating for them to (continue to) participate. The design of tricot could benefit from building in more interactions in an efficient and cost-effective manner, and increase the feedback participants receive throughout the process. Feedback can refer to any type of progress update, and doesn't necessarily mean providing participants with the results of the trials alone. For example, sending participants with smart phone a photo of a well-planted trial will help them assess whether or not they planted their trials properly. Or sending out a quick message (through any appropriate medium) on where we currently are in the research process and what the next step will be, offers a simple way of keeping participants informed that the research process is still ongoing. There are numerous ways of building interactions into the research process, some of which I will explore further in the design phase.

Table 3 summarises eight recommendations for the design of participatory processes. These recommendations were inspired by De Vente and Reed (2016) who analyzed which elements in the design of participatory processes might be universally applicable. Their recommendations might offer opportunity areas on different levels in our design process, varying from interaction design to higher level service design. We will use them to explore possible design solutions in the next chapter.

Table 3: Design recommendations

Recommendations	Description	Outcomes
Adapt data collection formats to the participants	Use language and forms of information adapted to the education level of participants. Design user-friendly and appropriate paper forms or find alternative ways to collect the data	Better data quality, delivering on the learning outcomes
Obtain explicit and written informed consent from participants	Provide participants with relevant information on the purpose of the research, the risks and benefits of participation and what is expected from them.	Establish trust and accountability, increased understanding on the process. Flexible solutions and goal attainment. Higher engagement?
Increase the number of interactions participants have with field staff and/or researchers or facilitate more group interactions	Provide regular feedback to participants in terms of progress, results and responsibilities throughout the research process.	Increased engagement, less confusing about what it expected from them, being part of a process, more information dissemination, increased learning?
Define clear learning goals for participants	As part of project design articulate the learning outcomes of individual participants and identify how to measure this.	Direct and indirect learning outcomes of the goals are measurable.
Select participants carefully	Ensure that multiple users are able to participate in the research. Identify recruitment criteria which offer s everyone equal opportunities to participate. Focus on recruiting research-minded participants from all user groups (from struggling to business farmers).	Increased representativeness of the results, non-exclusive voluntary contributions, higher chance at completion because of voluntariness of the approach.
Provide feedback on the results of the trials in an appropriate manner	Feedback delivery on the results in an appropriate manner to ensure learning goals are attained.	Learning, increased trust, accountability of researchers and field staff to deliver on learning outcomes
Invest in process design	Offer support to implementers in carrying out the approach, offer training and ensure that all stakeholders subscribe to the goals of the approach.	Increased acceptance and implementation of the approach
Define clear roles for researchers, implementers and field staff	Consider the responsibilities, benefits and trade offs of different stakeholders and identify where potential bottlenecks (?) in the implementation journey might occur.	Increased robustness of tricot implementation

6.6 Discussion

As a first step in the design synthesis, I modelled the data into alignment diagrams to present the themes, insights and hunches discovered in the research phase of the design process. The advantages of creating alignment diagrams is that these maps can compact a lot of data, create a visualisation on where in the process opportunities for growth are situated, diagnose problems and expedite a common understanding of the user journey (Kalbach, 2020). The visualisations help us to discuss the issues in the user experience and redesign the brief. In the initial brief the designers of the approach mentioned two challenges: (1) the lack of established and scalable methods for engaging participants in setting for research priorities and (2) a lack of design for engagement to motivate participants to contribute quality data, take up more responsibilities and sustain their participation. We reframed this to the following question: *how might we set up consistent information and feedback delivery throughout the research process to deliver on expectations and motivations of participants*?

By listing the constraints (hurdles and opportunities) and exploring the problem space we were able to suggest several design recommendations. These prompts should be seen as opportunity areas that could aid and add some direction to the design process. We discussed the difference between the ideal state and the future state and set the first boundaries for our design process. It is important to realise that in any design process there is no 'right' or 'wrong' choice, there are usually many paths that might lead to more profitable or beneficial outcomes or could lead to the desired end-state. Documenting the choices made in the process becomes important not only as a validation (it should be replicable) or justification (based on these facts, we made these choices) but more so as a document as a source of inspiration for further testing and iterating. The future state refers to the high-level steps which we will take to create or redesign the research approach. The ideal state describes the optimal implementation of tricot research just as the designer intended. Whilst it is easy to dream up an ideal state after our initial discovery phase, designers usually have to deal with constraints of their own. For example time constraints or budget or context-in-use are all factors that will alter the likelihood of achieving the perfect 'ideal state'.

6.7 Reflection

There is a risk that after extensive research at the forefront of the design process, we assume that all the insights are taken into account once we start building the designs. We fly in and start working on our prototypes and designs and forget the design rationale and recommendations. The choices were influenced by the themes and discoveries made in the research phase of the design process. Documenting the process helps to shed some more light on how these seemingly implicit decisions that gave form to our designs might have taken place. Synthesis ends the research phase and moves the process into the ideation phase. In this case, we worked through all our materials and findings as a team to ensure everyone has access to the same information, and in addition to the modelling activities described here, this formed our implicit process of synthesis. In this chapter, I presented synthesis as a linear and abductive process for the sake of readability. Here I provide some insights in the actual synthesis process based on meeting notes and sketches of the process.

The different steps of dissecting and visualising the user journey help us consider the tricot experience from a participants' point of view. A few of these steps overlap, meaning I present the same data multiple times in different ways. This represents how we went through the process. Initially by analysing and extracting information from user interviews by myself, and later by carrying out sense-making exercises to get a better understanding of the context and create common ground as part of a team (see chapter 8 for a full description of this collaboration).

The user experience map went through several iterations. For example, the experience map in figure 18 represents a user experience that wasn't created with a specific persona or goal in mind. It simply mapped the actions and interactions of participants in tricot research and added feelings and thoughts as an additional layer. Taking into account different types of users with different types of needs might lead to a very different outcome. See figure 19 as an example of an alternative visualisation.

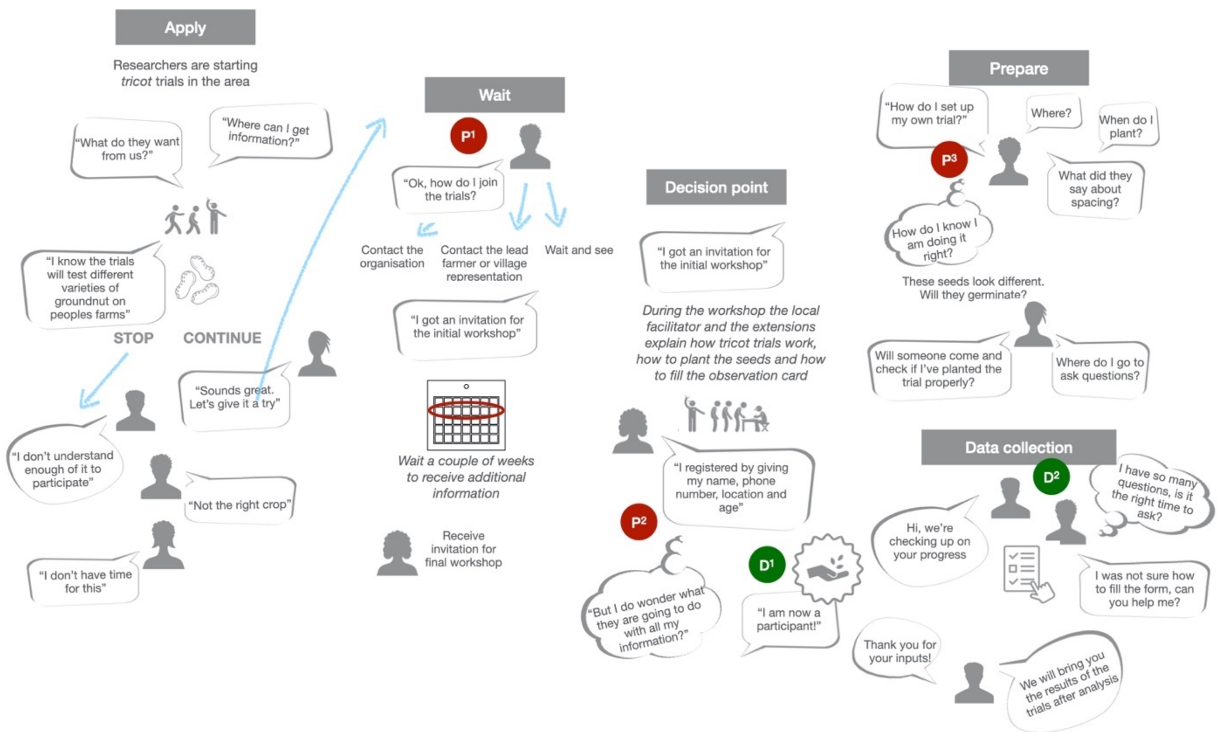


Figure 19: Visualising the narrative user journey

Instead of a table format, I visualised the thoughts and considerations of the user. For example the red circles with p1 and p2 signal to pain points in the user journey. The green d1 refers to a 'moment of delight' and flags an engaging experience in the research process. In this particular user journey map I highlighted the opportunities, insights and pain points. Spending more time on the visualisation and simplifying the format enhances its readability and ultimately also its ability to communicate a clear message. The experience map used in the design process (figure 18) contained many layers and might be difficult to interpret for anyone but the author. The main purpose of these user journey visualisations are to create common ground by showing a user experience which can be discussed in detail and as a tool for analysis and reflection for those who compile it. Overcomplicating the visualization will lead to ambiguity in interpretation and might fail to provide such common ground.

By visualising the tricot experience from the participants' point of view, the interactions (or touch points), expectations and barriers to experience become clearer (see figure 19). I describe the pain points or barriers to experience, perhaps in a lot of detail, however I do this as one of the steps in the process of framing the problem. The field studies represented unique implementations where elements of the approach might divert from how the tricot approach was originally intended. This user journey map will probably look different for other tricot projects. Certain pain points might be considered to be 'part of the process' and acceptable, whilst others might prove to be breaking points in the process and therefore require more in-depth scrutiny to discover how this informs and affects problem framing.

Illustrating the user journey in a experience map offers benefits in terms of visualising the interactions and bringing out implicit knowledge in terms of the human context. User experience maps contain a lot of detailed information and represents complex data that otherwise would be hard to take in all at once. User experience maps are particularly useful as tools to guide design discussions by providing focus and reference. These alignment diagrams offer the following opportunities: they can display a large amount of data at once, they can be used as a document for the diagnosis of problems, indicate where in the process we can create value, draws up a common big picture or function as a shared artifact. User journey mapping can be used in strategic decision making. Because much effort is put into the visualisation of a user experience, these documents tend to survive for longer than a written report increasing the longevity of the information.

6.8 Conclusions

This process of collecting and compiling research findings, experiences adding insights derived from literature is called design synthesis. Analyzing and restructuring all these bits of information helps to set the priorities for design and to demarcate the problem space. Rather than signalling a problem and directly go into a stage of solution-finding, taking time in the front end of the design process to digest and discuss all the insights that are available to the design team, can help to reframe the initial problem space. Here, the assumptions that we had before we started the process, did not hold true. For example, the engagement of participants as well as low accountability towards the end-user of researchers and implementers were flagged in the initial brief as the main problem. However, through synthesis, other issues for example the importance of having a clear value proposition to communicate to participants, setting learning outcomes, and consistency in communication became important factors that influence participants' engagement. Standard practice wouldn't have surfaced this type of information / might not have flagged this as an important issue.

Chapter 7

Ideation

7.1 Introduction

The next step in the design process was to brainstorm ideas and decide which ideas can be turned into prototypes for field testing. In the design process, we have now arrived at the second diamond in the Double Diamond model (see figure 20).

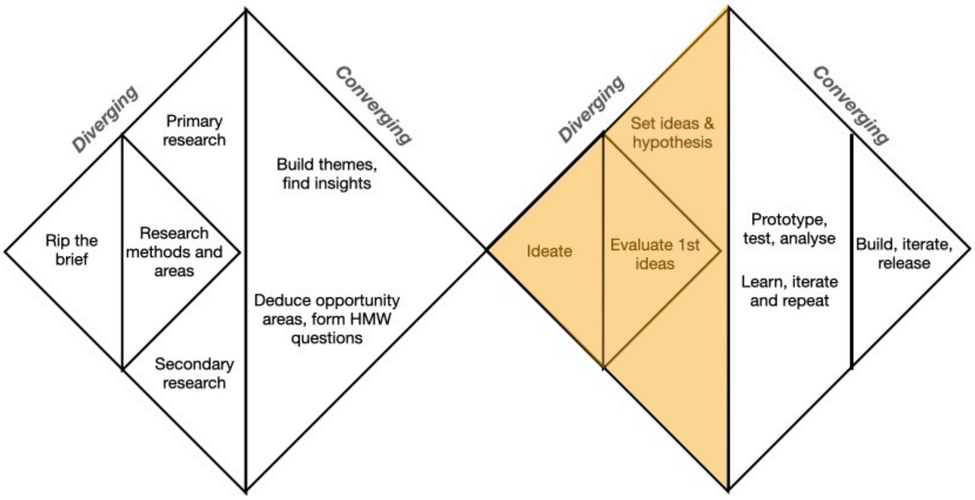


Figure 20: Stage 4 in the design process

We use the description of the problem space, which resulted from the design synthesis phase, as the guidelines for designing solutions. Here we want to widen the space again as visualised in figure 20. The double diamond model represents a repeated process of diverging and converging.

One of the first activities in the ideation process was to conduct a precedent study. These precedents are not intended to be prescriptive in the sense that we would aim to copy-and-paste the different elements into our situation. Rather than perform iteration on the existing situation, the intention of collecting these precedents is to push our imagination of possible solutions. It is meant to inspire many design solutions without prioritization in terms of feasibility or likelihood of being implemented at this stage.

We ideate by sketching every possible idea that might offer a design solution, initially without setting too many boundaries in terms of feasibility, and in a second step, we evaluated these ideas and prioritised which design ideas are going to be taken forward in the next phases of the design process. In the next chapter, we assess the feasibility of building and testing the prototypes and start creating mock-ups. Here we simply document the process of prioritizing the different ideas and narrowing the design space.

7.2 Methods

Empirical work was conducted as part of a summer school project in 2018. The project 'Engaging Forms for Participation: how can farmers in developing countries have meaningful input into agricultural research that affects their livelihoods' involved students with an HCI or interaction design background from the University of York in a collaboration with Bioversity International and Lutheran World Relief from their respective regional offices in Kenya. The following people contributed during various stages of the project. I acted as the project lead and collaborated with two interaction design students (Naoimh Murchan & Jonathan Skjott) from the University of York, field staff from Lutheran World Relief (Joy Wanza) who worked with farmers in our study area, Berta Ortiz Crespo, a research consultant responsible for implementing tricot trials in the area, Sebastian Deterding supervising myself and the two design students and offering advice to the team.

7.2.1 Precedent study

How can we best explore the solution space? We looked at architectural sheet design and playful architecture to draw inspiration on how to present the precedent. In architecture, the use of precedence is common practice. Most architects keep collections of magazine clippings, sketches, notes from site visits, and reference materials from architectural plans and literature to be able to draw inspiration from during future projects. These precedents are not a matter of copying ideas but each precedent is researched and interpreted by the user by studying its features, for example by looking at structure, scale, materials, aesthetic, details, social impact, use, context, and many others. Precedents communicate how they apply to a design, what lessons can be drawn from the example, and how they could be integrated to solve design problems (Pasman, 2003).

A design team consisting of interaction students from the University of York, consultants of Bioversity International and myself, undertook the precedent study. Having a team working together from different backgrounds enhanced the breadth of knowledge or experience that guided the search for precedent. The precedents were collected individually and shared with the rest of the team using Google Slides and further discussed during online meetings. Each team member compiled 1-2 slides or collages to represent the idea and sources of inspiration. Precedents were explored in an ad-hoc manner with choices depending on each team members' experience or interest in the topic. The search for precedent was ad-hoc where one precedent, an initial thought of how a service or product might provide the same affordances as we are trying to incorporate in our designs, led to the exploration of other - similar - precedents. Not all are represented in this chapter because we focused our analysis on a few in-depth examples.

Collecting precedents is not meant as an exhaustive exercise, rather finding inspiration to a reasonable extent in a certain phase of the design project. If at a later stage it turns out that we want inspiration from different sources, the whole exercise could start again. Precedent exploration was kept to a minimum in the sense that we had no intention to study it as in-depth as we would study a case study. We usually explored 1-2 similar types of products or services and left it at that. The guiding principle for precedent selection was large-scale user involvement and providing feedback to users. The purpose of this chapter is to build a display of reference materials kept in their raw form and after being discussed in the team perform nothing more than ideas percolating in the back of our minds.

7.2.2 Idea generation

Other than using the principle of 'sketching every idea' we did not use any 'formal' ideation techniques (see figure 21). We set out to present and discuss any ideas we had with the group. Using online brainstorm sessions we prioritised and worked out some of the ideas in more detail. The purpose of this process was to ensure that we explored ideas fully before we discussed the agility and feasibility of any of the proposed solutions. This allowed us to think creatively about possible actions that could inspire building the prototypes. Since the team took time before to internalise the entire problem together (see chapter 6: Design Synthesis), we assume that the team has a common understanding of the problem space in which the solutions should be placed. The ideation process starts with a list of issues that we have identified in the tricot research process, the design recommendations, and the ideas we collected from the precedent studies plus the individual expertise that each of us brings to the table.

We followed a general design process where we first discuss higher-level themes and do some idea generation. As a first step, we sketched every possible idea. We let quantity supersede quality at this stage of the idea generation process. Each design team member prepared several possible ideas to improve the design of the tricot research approach and presented them in 2 minutes. The other team members got to critique them in 3 minutes. Each of us looked into a few of them in more detail, creating a more worked-out idea for the rest of the team before proceeding to make choices on where our focus will lie for building the prototypes.

Figure 21: Desk research and online brainstorming at the University of York (Photo: Naoimh Murchan, 2018)

7.3 Precedent study

In this section, we provide an overview of the precedents we explored to create a collection of references and inspiration by highlighting the elements that are insightful and useful for our design process. Besides inspiration and ideas, the precedent study provided us with examples of worked through solutions. We asked ourselves the question: how can we best explore the solution space? Does this precedent significantly contribute to our exploration of the solution space? And documented our process in terms of the insights (or a-ha moments), the questions it raised, the decisions and actions it brought.

From the interview study it became apparent that that feedback provision is an important motivator for sustained participation: From game design, we can borrow a categorization of different types of feedback (Hongyu, 2018). Cumulative feedback to emphasise the progress a user makes will provide them with a sense of accomplishment and keeps users engaged for longer. Cognitive feedback where the user receives positive or negative reinforcement' and learns' how to complete an activity as being part of the activity itself, and this will validate their actions. They know whether or not they are on the right path. Goal feedback where each action or step in the process has its own set of goals to guide users through the whole process and keep them engaged throughout. The user will feel as if each step in the process is a unit that they can complete and this adds to their sense of accomplishment, especially when the process from start to finish takes place over a prolonged period. In citizen science, communication of the scientific results is another important aspect of providing feedback. The scientific output in the form of results and publications should be a shared effort and acknowledgment for researchers and participants.

Currently, feedback throughout the research process is limited to 2-3 communication touch points (at registration, during data collection, and during the final workshop). Rethinking the feedback mechanisms could be a useful entry point in improving the design for engagement of the tricot approach. For example by exploring design elements that would enhance communication during the tricot research or the communication of the project results and scientific outputs. We focused in particular on examples in medicine adherence, learning, farming games, and citizen science projects. These four collections were chosen for various reasons. Medicine adherence was chosen for its ability to offer triggers at a set time and nudge its users to take action in a prescribed manner (for example through brochures or oral instructions given out by the pharmacy or health care professional). Learning apps or platforms were selected as an interesting area to explore further because it usually involves larger groups of participants in a single project and for their ability to set and communicate learning goals. We looked at farming games for their visual representation of agriculture, icons used, and other graphic design elements used to simplify its understanding. Lastly, we looked at online citizen science projects to draw inspiration on the way they offer learning outcomes for their target audiences and what elements we might want to use in our designs.

Our search for precedent started with a scientific article on the gamification of medicine adherence in epilepsy (Rahim and Thomas, 2017). They describe that incomplete medicine adherence is often caused by a lack of support, lack of motivation, and forgetfulness leading to poor adherence. Strategies to improve medicine adherence are generally focused around better communication between the healthcare professional and their patient. For example by simplifying regimen characteristics, modifying patient beliefs, and evaluating adherence. However, as the authors explain these types of interventions often take place during direct contact points between the healthcare professional and the patient and do not include strategies for patients who are left on one's own accord or do not have frequent interactions with a healthcare professional. The authors draw inspiration from The Wheel of Sukr (see figure 22) compiled by Al Marshedi *et al.* (2015) to come up with a set of guidelines using gamification to increase motivation for medicine adherence.

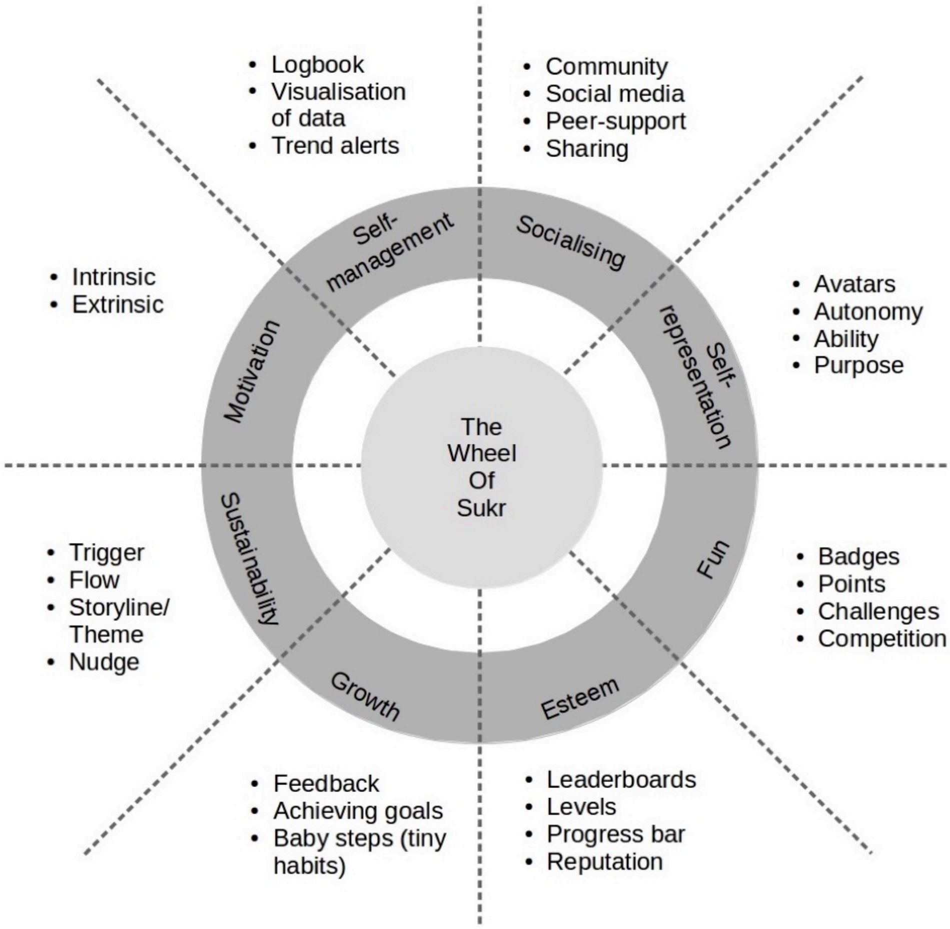


Figure 22: The Wheel of Sukr (Al Marshedi et al., 2015)

The guidelines consist of 8 components further adapted from 'The Wheel of Sukr', see figure 22. For example, *fun* refers to creating an engaging experience by designing a user-friendly interface and a system of rewards and badges. *Esteem* could be increased through the use of social media offering the ability to rank themselves amongst others with similar medical conditions. However, the authors do caution that it is important to do so in a positive manner as to not further discourage the user. *Growth* could be achieved by building a feedback system, for example offering weekly summaries on how well the user performed or offering rewards when the user reaches a specific target or goal. Information to further educate the users on their illness could be incorporated into the feedback system. Rather than focusing on extrinsic motivators, for example, badges and rewards, the authors suggest increasing the intrinsic *motivations* of users by allowing them to manage their own condition and set their own goals. Through the use of social media, the platform could also support users *socializing* with patients living with the same conditions. *Sustainability* of use can be achieved by building in options for push notifications that serve as nudges to start logging data or linking it to other monitoring apps (for example Apple's Health app) to increase its benefits. They also mention the possibility to add a narrative to the platform so that the user feels as if it is completing a journey which could potentially enhance continuous engagement. *Self-representation* can be achieved through the use of avatars and frequent use of addressing the user by their user-names or users being able to set their own goals and achievements for the process. The platform could serve as a personal log for the user, documenting their seizure history and to be able to track any improvements and relate this information to medicine use. Similarly, the capacity for *self-management* could be increased by building in to-do or checklists or reminders about upcoming health checks.

7.3.1 Medicine Adherence

We looked at medicine adherence to find inspiration on persuasion techniques (reminders for taking medicines) at set intervals in the day. What triggers do medical professionals or pharmaceutical companies use to influence their client's behavior to voluntarily take their medications as prescribed? How do they alert the client that it is time to take their medicines? What type of support do they offer and in what form?

An example of an app that has used some of these elements in the design of its user interface is megameds Pharmacy (figure 23). This android app was in its start-up phase in 2018 during our precedent study. It is current unoperational as it was unable to raise funds.

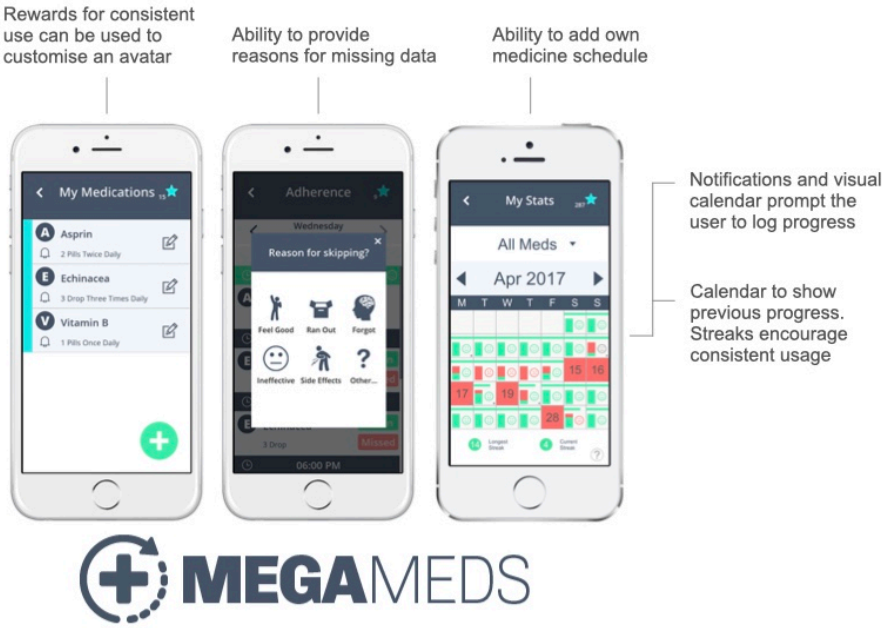


Figure 23: megameds medicine adherence tracking app

We could easily imagine most of these elements mentioned above to be useful in the further design of the tricot approach. Affordances we felt were interesting were the way the authors suggested allowing users to set their own goals and facilitating the connection to a group of like-minded people, bringing them together in an online community, sharing achievements, and being able to compare their situation with others having the same medical conditions, seems like valuable contributions to the design of the tricot approach. Having access to a digital environment that supports all these elements using relatively simple phones or technologies, might ask for additional design considerations. However, the mere considerations on how these different elements might fit into the designs in alternative ways could prove to be useful for the thinking process.

Continuing our search for medicine adherence, we came across Vitality glowcap, an Internet-of-Things solution that glows and offers audio cues when it is time to take medication. It is designed to fit most medicine bottles. It detects if the bottle has been opened and if it hasn't after a scheduled dose, it will initiate a phone call to the user to remind them to take their medication (see figure 24).

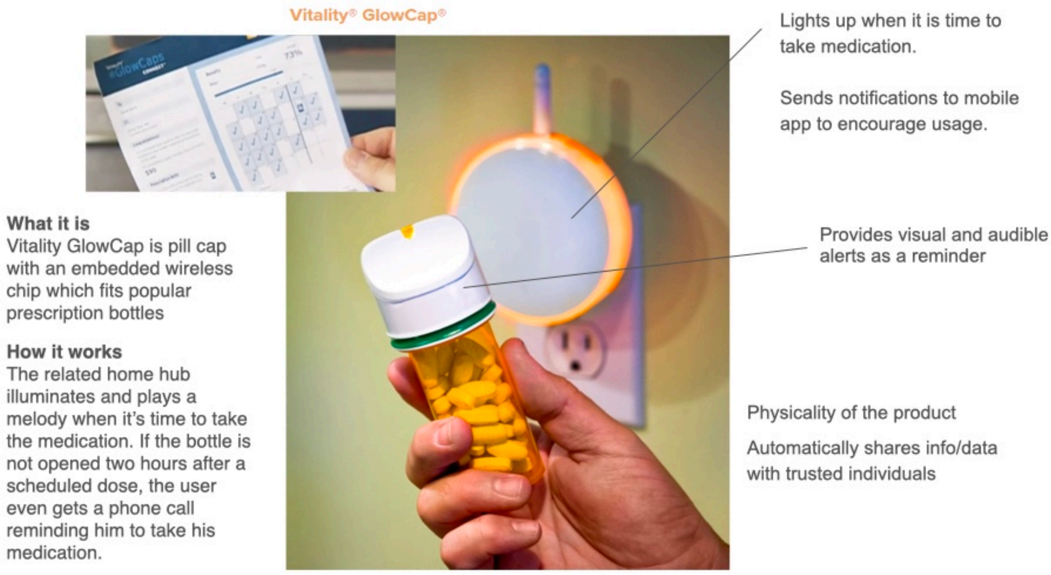


Figure 24: Vitality glowcap for medicine adherence

The glowcap takes the visual and audio cues away from a digital platform or mobile phone and places them inside the medicine cabinet. The physical presence of a product that reminds the user to take their medicine at set times, is an interesting form of action avoiding the use of a smartphone. The connection to the internet and its ability to contact trusted individuals in case of non-adherence could be potentially life-saving in terms of medicine intake. The user receives a weekly report to show their medication intake. It can also order refills. The idea that non-adherence could be used to alert a local facilitator, who can then follow up directly could also be an interesting thought for the design process.

7.3.2 Online learning platforms

Learning platforms tend to engage a large community of diverse users into their service. Two key aspects of online learning are the ability to transfer knowledge without requiring an in-depth clarification (e.g. Easy-to-understand) and provide feedback on users' progress (e.g. Rate how well they perform a specific task). Learning platforms should have clearly defined learning goals. We were particularly interested in how they keep participants engaged during the process, how they define and communicate learning goals and how they offer feedback to its users. In addition, we also looked at the way they use visual elements and their value proposition.

Duolingo is a language learning app with a heavy use reward system of badges, leaderboards, and points. This makes the progress you make in learning a new language visible and measurable. They have a quick onboarding process where they ask a few questions that will determine the users' goals and use pattern and then starts with the exercises straight away. A placement test can determine at which level the user should start. Lessons start simple and build up in difficulty. Progress is tracked in 'skills' which are composed of sets of mini-tasks to help users track their progress more easily. Users can set a target in minutes per day of gameplay which is translated into XP (experience points) and is visualised with a progress bar in the app or on the computer screen. Juicy feedback is provided after each question. These elements are all meant to play into feelings of competence. Users who have not logged in for a few days are sent notifications to draw them back to the platform. However, the platform is often criticised for its incessant use of notifications. Visualizing a users 'winning' streak is used to increase continuous engagement with the platform. Duolingo uses two main elements to track progress: the completion rate of learned skills (e.g. The mini-tasks a user completes as part of the big skill of learning a language) and the number of days a user has consecutively played (Huynh and Iida, 2017). It uses game-like elements, for example, a reward system with badges, levels, and challenges, and by offering juicy feedback to keep people motivated to keep playing.

We could use some of these elements to inspire design solutions. For example, the way duo lingo breaks down the big task of learning a language into bite-size pieces. For tricot, we could similarly visualise the process of planting a trial into mini-tasks to simplify the process of tracking individual progress. Finding ways of offering juicy feedback during the trials without relying on digital communication, could be an interesting challenge for the design team during ideation. Their quick onboarding process could serve as inspiration to alter the registration process of tricot participants and add the ability to quickly assess their expected levels of performance. The audiovisual cues and easy pictograms could inspire interaction design elements.

A learning platform targeting a specific subset of learners is the Kiron Campus (see https://campus.kiron.ngo/). Kiron Campus offers online learning opportunities for refugees. Designing a service for a special user group ensures a more tailored product than if they were to offer online learning opportunities for everyone. Kiron offers "free access to high-quality education for academic, professional, and personal growth" that can be used as a standalone certification or as transitional education towards enrolment at a regular university (figure 25). It does so through self-paced online courses, live online collaboration, study groups, and by providing student services, for example offering guidance for and supporting university applications. As a learning platform it aims to adhere to high accreditation standards and in its position as a non-governmental organization, it aims to promote educational equity.

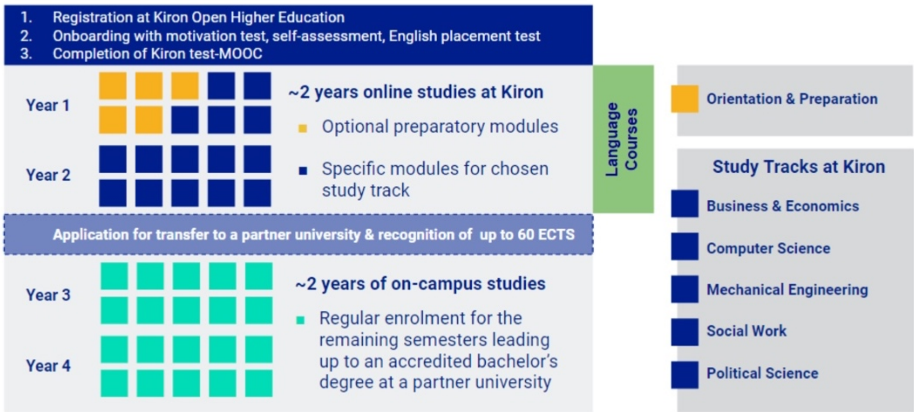


Figure 25: Kiron's academic model in Rampelt and Super, 2017

Kiron Campus user interface provides a visual overview of the different services and tracks the progress of (interim) goals. Kiron Campus offers modularised and tailor-made curriculum provided by external academic partners. The collaboration with and reuse of existing content and bringing it together in a tailor-made lesson plan suited for a specific user is an interesting way of providing educational content.

Learning Creative Learning (LCL) is "an online course and community of educators, designers, technologists, and tinkerers exploring creative learning" (https://lcl.media.mit.edu/). The online course offers live events, video lectures, and reading materials. It focuses on a special user group of education designers. There is no heavy visualization of progress, rewards. The materials are organised in weekly lessons plans. It is easy to browse through the content and cherry-pick what you are interested in learning. It lacks a game-like interface which might explain part of its appeal for the community of educational designers (e.g. Professional users who will use this resource during working hours). This presents a clear alternative for other examples represented here which rely heavily on gamification of its educational content. Perhaps it is not always needed to incorporate juicy feedback and reward mechanisms, and seek out manners that align with the target group's most natural way of learning.

Typing Club is an online program for learning how to type using a qwerty keyboard. It offers 685 mini-lessons of progressive typing tasks which unlock upon completion of a lesson. It teaches using clean and to-the-point instruction videos, graphic elements, and feedback (see figure 26). Progress is tracked on a home screen which provides an overview of all lessons and visualises the users' progress. Where duo lingo almost overdoes it with its juicy feedback, Typing Club can provide the same (or more) feedback in a unique and less obtrusive/prominent manner. The learning outcome is clear: at the end of the journey, a user will be able to type without looking at their keyboard (e.g. Touch typing). Visual elements such as moving hands simplify the instruction process.

Figure 26: User feedback in Typing Club

7.3.3 Online farming games

We looked at online farming games to study the visual representation of agricultural activities and the reward and feedback system of actual games, as opposed to the examples of gamified learning experiences. Hay Day (see figure 27) is a mobile game application where the user has to take care of a run-down farm. By performing agricultural activities called missions, for example planting seeds, growing crops, and selling produce, the user can earn points that can be traded in for production buildings, livestock, and decorative items. The user also earns experience points which are used to level up. The game offers a clear narrative of the journey that lies ahead, and tracks progress with bold status bars and level-ups. Juicy feedback is provided after every micro action and level completion. Even juicier level-ups are provided after every 5 levels. They also offer clear incentives on why a user should try to level up by showing what they could achieve or acquire in the future. Activities are noticeably designed to keep users engaged for the longest time. The game offers high-quality graphic design and game functionality.

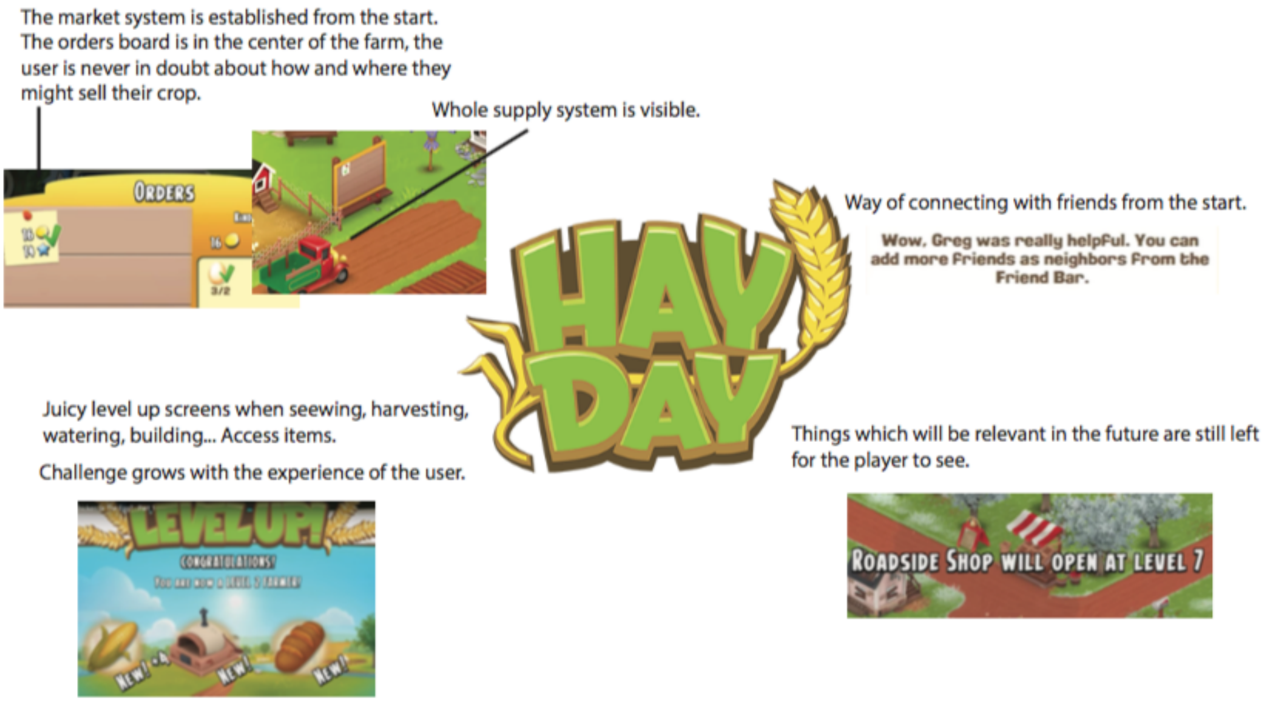


Figure 27: Hay Day online farming game

The use of a clear narrative to structure and communicate the user journey that lies ahead might be interesting for simplifying a training process or to communicate the value proposition to participants. The ability to anticipate future actions ("if I complete this, then I will be able to get access to this…") will help to keep people engaged for longer. High-quality graphic representations and juicy feedback are useful building blocks in a gamified approach to participatory research.

7.3.4 Citizen science

A well-known example of online citizen science, Galaxy Zoo, asks participants to classify a large number of galaxies by eye (see figure 28). The idea came up when researchers found out that computers were not very reliable in their classifications of SDSS images.[6] Their website allows a user to choose between getting started with the task immediately or learning more about the project. When choosing 'Get Started' a user will be guided through a brief tutorial explaining the task at hand, allowing users to opt-out for a messaging study and general information. Further instructions on how to make the observation are provided as part of the multiple-choice questionnaire. When choosing 'Learn More' the user is directed to the web pages containing information on the science behind the site, the team, and the results. A data archive is available to everyone which contains all the data files generated by the project which can be used on a creative commons license. This data archive also contains a visualization of the decision tree showing how users interacted with a specific project (see https://data.galaxyzoo.org/gz_trees/gz_trees.html). This shows the laddering-type questions that make up the questionnaire.

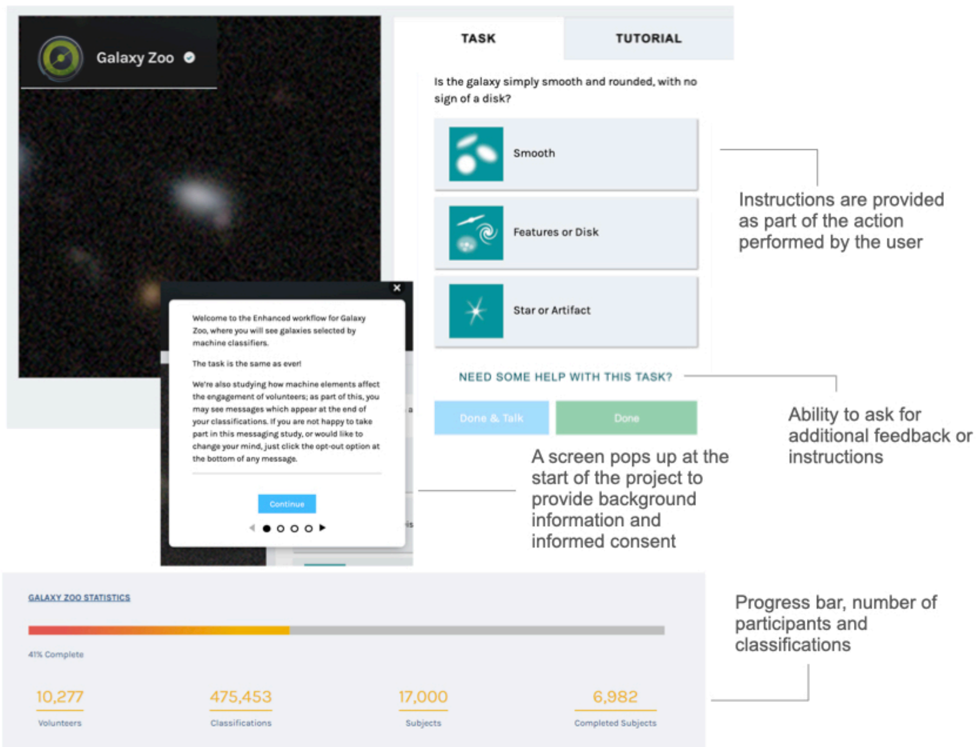


Figure 28: Design elements for Galaxy Zoo's online platform

[6] Sloan Digital Sky Survey (see https://en.wikipedia.org/wiki/Sloan_Digital_Sky_Survey)

The instructions provided as part of the activity are something that tricot could improve on. Tricot currently uses one-tier questions, but the questionnaire could be redesigned to include follow-up questions to collect more specific information on the observations (thus increasing the fine-graininess of the data). Showing the overall data in terms of the number of participants and number of completed trials could be useful to increase engagement with the overall results of the trials. The scientific feel of the website as well as the amount of information offered in a non-overwhelming manner where users can choose the amount of background information they would like to take in at any given time. This caters for different kinds of users: those who simply want to complete the tasks and those who are interested in learning more.

7.3.5 getfeedback

Getfeedback consists of a mobile application that allows users to easily set up customer surveys with customised branding and imagery, a customer experience platform (CX platform), and the ability to collect direct feedback through email and SMS (see figure 29). The CX platform allows the user to bring together feedback from multiple channels and analyze and organise the data using different visualizations. For example, insights into what drives the customer experience, tracking progress, and potential improvements on touchpoints that impact customer loyalty.

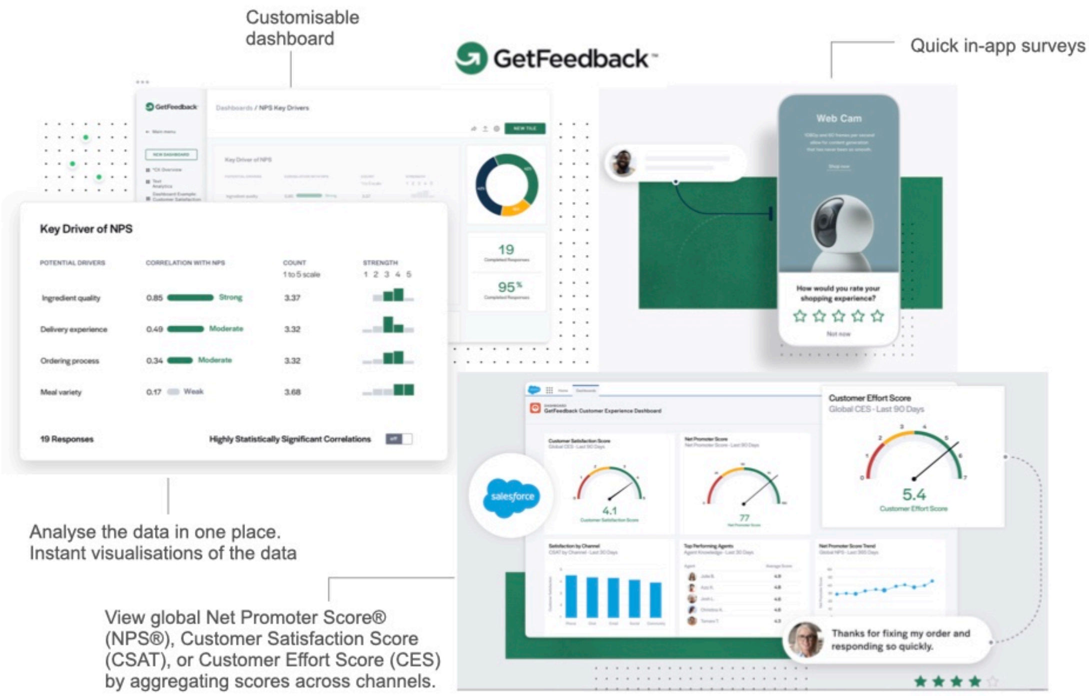


Figure 29: getfeedback's digital platform

The concept of collecting data on the customer experience is a useful frame for monitoring the use of the product or service, perhaps to assess data quality or to be able to continuously seek out to improve the product or simply to assess its usefulness in a specific context. The platform's ability to bring together data from various sources into one analysis is also a useful design consideration. Especially considering tricot data collection uses multiple tools. The customizable dashboard lets users with different research interests select which insights are most valuable to them. Being able to view these insights in real-time as the data is still being collected, would help researchers to carry out tricot trials continuously, rather than having to rely on distinct research cycles (as long as the crop's growing conditions are not seasonable). Having built-in and recognised indicators in the analyzed data helps users extract useful data for their outputs. Being able to use clear visual representations of the data, will also enable users to communicate feedback on the results to participants in the tricot trials.

7.3.6 Pest and disease identification

The Plantix app (https://plantix.net/en/) is designed to identify plant diseases and pests for 30 different crops (see figure 30). The user takes a photo of the leaf or stem of the plant that is affected by the pest or disease and the mobile application will search the database for a result. The user receives a factsheet with information on the most probable pest or disease affecting the crop. The user can also browse the database to identify the pest or disease themselves. It takes three simple steps to get the results: select the crop in the menu, take a picture of the affected part of the plant and upload it, receive the diagnosis. It currently identifies the most common pests and diseases (654 results in 2021) with 74% accuracy (Wang *et al.*, 2020). Feedback is provided in the form of images, a general description, likely symptoms, and suggestions for treatment. In addition, it can link farmers to a wider community for further advice or discussion.

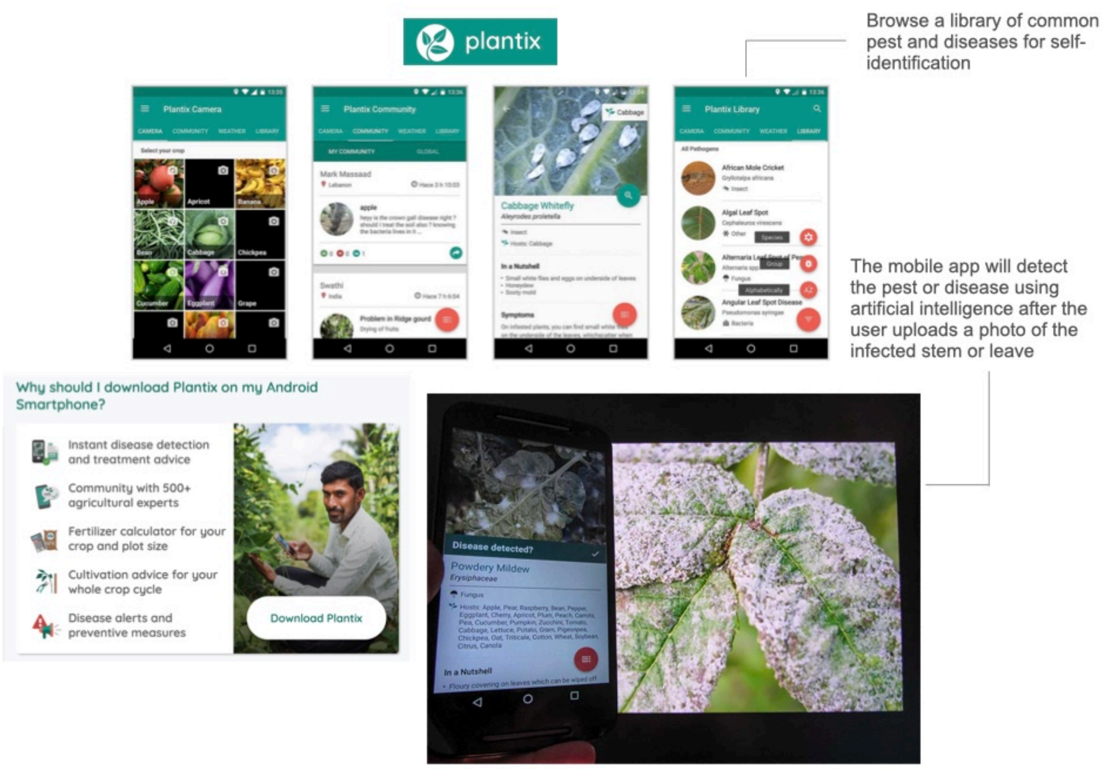


Figure 30: Plantix android-based app

The ability to provide a near-instant diagnosis using deep learning can be a useful design element to explore further. Pest and disease identification is a sought-after skill for farmers participating in the tricot trials. Being able to retrieve this information on a mobile phone makes it possible to bring this information into the field. It enables farmers to access knowledge that was previously not available, especially in rural areas in low-income countries where limited access to internet prevails.

7.4 Affordances for design

In the previous section, precedents were introduced and their main concepts described. Whilst the precedents came from a variety of sources, they have several commonalities in terms of their design. In table 4 I list all the affordances that were mentioned in the previous section and highlight which examples make use of these affordances. I created a non-exhaustive list of possible design options to use as a flexible collection of references during the generative stages of the design process.

Table 4: Affordances of precedent

Affordances	Wheel of Sukr	Mega Meds	Glow Cap	Duo lingo	Kiron Campus	LCL course	Typing Club	Hay Day	Galaxy Zoo	Get Feedback	Plantix
Progress tracking											
Progress or status bar	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Rewards and badges	✓	✓		✓			✓	✓	✓		
Ranking and leaderboards	✓	✓		✓			✓	✓			
Audiovisual feedback	✓			✓			✓	✓	✓		✓
Anticipating future events				✓		✓	✓	✓			
Winning streak		✓	✓	✓			✓	✓			
Background information (learn more)						✓			✓		✓
On-Boarding											
Narratives								✓	✓		
Quick onboarding process				✓		✓	✓	✓	✓		
Just-in-time instructions							✓	✓	✓		
Feedback mechanisms											
Realtime data analyses and visualisations										✓	
Individual feedback on the results	✓				✓					✓	✓
Reminders (push notifications)	✓		✓	✓				✓			
Juicy feedback	✓			✓			✓	✓			
Socialising											
Community of like-minded individuals	✓	✓			✓				✓		✓
Connectivity to social media	✓			✓			✓	✓			
Connections to other apps	✓		✓							✓	
Customisation											
To Do lists and checklists (self-management)	✓	✓			✓					✓	✓
Personal goal-setting	✓	✓			✓					✓	
Personalisation (design avatar)	✓	✓						✓			
Aesthetics											
High quality graphic design				✓			✓	✓	✓		

These affordances can be aggregated into seven ‘categories’ which are further explained below:

7.4.1 Progress tracking

Progress tracking involves visualizing what activities have already been completed and what activities remain. It creates the opportunity to hand out small ‘rewards’ or feedback on how users are performing. Badges, leaderboards, and points are all affordances for progress tracking. Status bars, either by providing information on the success of the project as a whole (such as in Galaxy Zoo) or as rankings to be able to rate individual success (Duolingo) are simple methods to visualise progress and increase engagement. Simply adding ‘points, badges and leaderboards’ will not make it automatically more exciting (Chou, 2016). Finding inspiration in basic game design elements for progress tracking and applying them to an already well-designed service can enhance the user experience.

7.4.2 On-boarding process

Several insights can be obtained from the game-design training mechanisms. Games such as Hay Day offer a narrative to the user, a storyline that explains why the user is placed in a certain context, and what the goal of the game is. The narrative is woven into the gameplay and user instructions are also provided during the game. Galaxy Zoo offers users the option to ‘Learn More’ or ‘Get Started’. When clicking the ‘Learn More’ button they will be able to access background knowledge on the project and astrophysical content knowledge. Several precedents follow the ‘Get Started’ approach and offer just-in-time instructions. Galaxy Zoo teaches its users how to classify galaxies by providing instructions during each question by guiding them through a decision tree. Typing Club is another good example of this by visualizing the hand movements across the keyboard. Quick onboarding processes are found in Duolingo, Galaxy Zoo, and Typing Club where users can start the activities immediately without having to register first. This allows the user to first gain experience with the activity before committing themselves and providing personal information.

7.4.3 Progress feedback

Communication touch points throughout the user journey are important points of interaction between the user and the product or service, not only for instructions or delivering information but also to provide and receive feedback. Providing feedback after each completed micro-action offers users validation that their answers were received. When used in combination with an instant assessment, the user can gain confidence that the task is being completed as expected. Hay Day and Typing Club are examples of this. Galaxy Zoo offers a choice between a 'Done & Talk' button for users to gain additional feedback or discuss with the community when users are unsure of their answers.

7.4.4 Juicy feedback

Juicy feedback exceeds 'regular' types of audiovisual feedback and can be used to increase feelings of competence or to diversify the feedback to keep things interesting. Deterding refers to juicy feedback as "varied, unexpectedly excessive sensual positive feedback on small user actions and achievements" (Deterding, 2015:313).

7.4.5 Foreshadowing future events

Duolingo and Typing Club show a visual overview of all the lessons that are yet to come. Hay Day's gameplay constantly hints at future events that will unlock after completing a level or performing a set of tasks. This method is used to prolong user engagement or ensure that users will return to the service. Similarly, user streaks are a measure of how consistently users use a service. In Duolingo, a streak increases for every day the user completes a lesson. In Megameds a calendar shows a green or a red mark for each day of completion. Winning streaks are used in games to mark a series of uninterrupted successes. In Hay Day winning streaks are rewarded with 'boosters' which are tools the user can use to complete tasks more easily. Streaks are a direct motivator for the continued use of the product or service.

7.4.6 Reminders

Hay Day and Duolingo send reminders to the users if they miss a day of gameplay. Vitality glowcap uses audio and visual reminders as main feedback mechanisms: for example through a wall light that starts flashing when it is time to take their medicines. Or by sending a message or placing an automated phone call to the user. Warnings can also be sent to family members or health care professionals.

7.4.7 Customisable feedback

Feedback collected from customer surveys is analyzed and displayed in the getfeedback software. Getfeedback allows the user to configure data visualizations to display feedback differently. This automated analysis is a useful tool for generating quick insights into the customer experience.

7.4.8 Socializing

Connecting users to a community of like-minded individuals can enhance the user experience by offering designated online communities. In medicine adherence, online communities offer support, share knowledge and empathy in the sense that they are not the only ones going through this. Kiron Campus targets a vulnerable group in society: young refugees and asylum seekers. Offering this group a platform where they can discuss the specific challenges in terms of education or their personal situation and providing support, has the potential to significantly enhance their ability in completing their studies. Plantix offers a community with access to over 500 agricultural experts. Social media can provide an outlet for 'bragging' or sharing achievements. For example, Rahim and Thomas (2017) describe people using the hashtag 'seizure-free' to indicate how long ago they had their last seizure. Games such as Hay Day offer the ability to connect with Facebook to see which of a users' friends play the same game and allow them to help out on each others' farms.

As we have seen from Vitality glowcap connectivity with third-party apps or platforms can significantly enhance the product or the service. Getfeedback integrates its platform with Salesforce, a leading customer relationship management software package.

7.4.9 Customization

Getfeedback is a good example of offering a fully customizable service. The user gets access to a dashboard where they can manage their projects, set their goals, and collect and analyze the data in various ways. Similarly, Kiron Campus lets users create their portfolio of educational resources and set their educational goals. Megameds offers the ability to insert and tweak their medicine schedule. Duolingo asks users to set their goals by indicating how much time they intend to play each day.

7.4.10 Aesthetics

We can see differences in the quality of the graphic design used in a service. Hay Day, Duolingo, and Typing clubs are games or gamified services and much attention is paid to the interface, the mechanisms, and principles of game design. Getfeedback builds software for evaluating the customer experience and has spent considerable effort in making data analysis and visualization easy to use. Aesthetics can help to create an enjoyable experience, however, the content and gameplay need to be in order first. Creating a highly engaging digital environment with strong aesthetics and functionality requires significant investment from a variety of experts. It is a matter of determining whether the outcomes justify such investment or whether simpler or analog tools might be just as effective in fulfilling the purpose as several examples presented here demonstrated.

7.5 Idea generation

We explored possible solutions and design ideas based on the design recommendations brought forward in chapter 6. The ideas are grouped together in nine clusters and presented below:

Figure 31: Collecting ideas for prototyping (photo: Jonathan Skjøtt, 2018)

CLUSTER 1: *Track 'n Trace*

Redesign the tricot research process to make the activities of local facilitators more rewarding and motivating. By making the process traceable and visualizing the 'progress' they make as they complete activities as part of their assignment. I provide two examples. First, compiling a performance appraisal and seeing all your achievements in a year on paper or in an app is an enormously satisfying process.

The second example I observed when conducting fieldwork in Western Kenya: Field books kept by extension agents as part of a research project helped them evaluate how many farmers they visited, when, distance covered, topics discussed. Their achievements became more visible and they were proud to take out the book and show to others what they've accomplished.

CLUSTER 2: *Tricot identity*

Social recognition of tricot participants' expertise on local seed diversity. Through their participation in tricot research, they become ambassadors of the approach or custodians on the new crop varieties and can offer support to new participants and share their knowledge on crop varieties in terms of best practices or new planting methods. They act as a valuable resource for researchers and implementers on how to improve the research process, or what crops to experiment with in subsequent cycles. In the following years, a new selection of tricot participants gets trained to be the 'custodian' for other crop varieties or technologies. Provide the opportunity to earn bragging rights and create a social platform for peacocking

CLUSTER 3: *Expectation management*

Design a value proposition to communicate the benefits and responsibilities to participants. With a clear value proposition participants know what is expected from them at each step in the research process and they can be more proactive in contributing data, obtaining results, and sharing knowledge.

For example, could we redesign the tricot trial package to make it possible to pick up a package and be able to start contributing without the intervention of local facilitators or researchers? What do we need to change in the current design to make it more suitable for self-implementation considering implementation in low-literacy environments?

Consent needs to be obtained from each participant to be able to use their data in analysis or store within implementing or research organizations. This process is built into the tricot process implicitly when field agents register participants using an app, however from practice we saw that this process was omitted. Consent is needed from each participant for their data to be used in analyses and stored within implementing or research organizations, and to prevent data from becoming unusable due to non-compliance with data laws (for example the GDPR in Europe or any national equivalents). Can we establish a social contract with each of the research groups or individual participants before commencing the trials? A social contract is a participatory form of establishing a contract between researchers and participants at the start of a research cycle. This will enhance the accountability of researchers and field staff to provide information and negotiate the terms of participation with the participants and ensure that all stakeholders are on board. And might help reshape any power imbalances that exist when researchers determine the 'playing field'.

We could consider offering various pathways to complete a trial that caters for multiple levels of participation with different support and activities offered to initial, sustained, and meta contributors. The way that software companies sell online subscriptions by varying the levels of support and functionality, comes to mind as an example.

Figure 32: Being able to select participation models

CLUSTER 4: *Tricot meets Farmer Field School / Farmer Research Network*

Increase learning opportunities and shift from practical learning to connected theoretical learning. This could be achieved by organizing participants in experimental research groups and supplying each group with templates and worksheets to facilitate discussions surrounding the experiments. Provision of templates and worksheets at set intervals will enable the ability to provide progress feedback and will keep people more involved during the research process as well as aid the data collection process so that participants collect the data at the right time.

CLUSTER 5: *Form design*

Redesign the existing paper templates used for data collection. The current data collection formats are the result of 3-4 iterations in actual field experiments where research cycle improvements were made based on the experience of the researchers and/or suggestions made by the participants. The forms have not undergone an explicit (re)design process using interaction design principles. Similarly, the feedback templates could be designed using interaction design.

CLUSTER 6: *Seed exchange activity toolkit*

To facilitate the exchange of seeds at the end of a tricot research cycle, we could design a seed exchange activity toolkit for local facilitators. The toolkit consists of templates and scripted activities that local facilitators can use during the final workshop to facilitate participants to obtain seeds from their preferred varieties from other participants in a playful way. For example, tricot research could be gamified by mimicking stock prediction markets where they can trade the crop varieties they have grown with others varieties grown by other participants. How well will their portfolio of varieties perform compared to the overall pool of varieties?

CLUSTER 7: *Facilitate social exchange*

Participants have indicated that the individuality of the trials (e.g. Being able to carry out trials on their own farm without having to comply with a group consensus in terms of their data, is a major benefit of participating in tricot research over traditional forms of participatory agricultural research. They do not have to reach a consensus with the other participants in the data that they will report and they do not feel they have to 'cover' for those who are not interested in participation. Not necessarily being contradictory participants also indicate that they prefer to be part of a group and describe a model where they can discuss their progress within a group of participants conducting similar trials, compare their successes, and interpret the results all whilst conducting their own trials. We could design affordances to be included in the research process to facilitate more interactions between the participants. For example by organizing regular meetings to discuss the progress of the trials. Or we could facilitate the interactions between different areas. For example, 5-15 participants from the same location are grouped as a unit and they compete with other groups. Their results are anonymised and shared with other groups with the provision of additional information on their management practices or contextual and environmental factors that could potentially influence the results. We could organise exchange visits. We could include the results from the neighbors into the overall results forms. Knowing in advance that the information participants themselves collect can be useful to other farmers and that this information can be shared as part of the process, might provide an intrinsic motivation to record this data more accurately and consistently. It provides participants with self-created learning opportunities and the ability to dialogue more effectively with their peers and with experts.

CLUSTER 8: *Continuous feedback provision throughout the research cycle*

Create more engagement by increasing the number of touch points throughout the research cycle. For example by increasing the number of data collection moments and sending templates at different times in the research cycle. Add a midway survey as an additional touchpoint to assess the level of engagement. Provide worksheets to the tricot researchers as a group facilitating instant data analysis and feedback on the results. Provide more extensive feedback on the results in data analysis workshops that take place after harvest that allow participants and local facilitators to interpret the data together. Add progress feedback that allows participants to track their progress and level of mastery. Improve the observation card (data collection template) to add more nudges for users to fill the data at specific times during the experiment. Or build in affordances for increasing participants' ability to reach out to experts when they have questions. For example the ability to communicate through SMS or voice messaging for sending feedback multiple times during the research process. Can they be connected to the other farmers in the group or from other groups, for example through whatsapp groups so they can help each other and share information? What would it take to facilitate this using basic phones?

CLUSTER 9: *Engagement of local facilitators*

When designing participatory research processes, the focus often lies on how to make the research process more participatory by considering how and when to involve users and which incentives to offer them in return for their participation. Not much consideration is given to the role of the local facilitators or extension officers in terms of their incentives and accountability towards the end-user. They are the most direct contact point for participants, however, they are often viewed as a bridge that allows information to flow from researcher to participant, or convey a message on behalf of the researchers and fulfill the task as they were instructed to. However, local facilitators have a responsibility within their respective communities and often fulfill multiple roles. This is even more relevant if the local facilitators are employed as extension workers by the government or local institutions, which is often the case in agricultural research. How can we restructure the process to ensure that they understand their responsibilities and are motivated to deliver? This requires a new assessment of the tricot approach with subsequent research into the motivation of the local facilitators. Considering the short time we have for fieldwork, this might not be feasible.

The current implementation of the tricot approach assumes local facilitators are knowledgeable and equally capable of setting up and implementing tricot trials. A high-level tricot manual targets the implementing organization who in turn is expected to train the local facilitators. Providing local facilitators with a toolkit for the implementation of tricot trials could enhance their understanding and capacity to engage participants in tricot research. For the initial workshop, we could design scripted activities or role-play cards for example to show the different stages of the research process. In addition, we could provide local facilitators with a manual with general agronomic advice related to the crops included in the experiment. This provides them with background information to provide basic support to participants in terms of pest and disease identification and management practices. They will also be more empowered to escalate any questions participants might have if contact details of available experts are provided in the manual.

7.6 Discussing the brief, re-brief

The initial design brief of the prototyping project read as follows:

> How can farmers in developing countries have meaningful input into agricultural research that affects their livelihoods?
>
> Together with the research for development NGO Bioversity, we are working on a participatory science approach called 'Tricot:' In Tricot, farmers try out and report their experiences with three varieties of new seeds or other innovations on their local farms. However, most of this work still happens with simple paper forms and gives farmers little initial say over what kinds of seeds or other innovations should be developed and trialed, to begin with. In this project, you will be prototyping and testing new, playful, more engaging analog and digital forms for farmer participation

in agricultural research together with students and farmers in Kenya.

After the synthesis process, we didn't move straight to designing the prototypes, instead, we brainstormed to come up with a list of ideas. At this point, we realised that we did not share the same understanding of the brief. This resulted in a series of ideas that were too widely spread and could do with more prioritization. It is quite common to come to a stage in the design process where the team decides to rip apart the initial brief and come up with a new list of priorities. We ended up conducting a *rebriefing* session after the synthesis phase. Design processes are seldom linear in the way they are carried out and this illustrates that fact.

Jonathan and Naoimh summarised the initial brief from their perspective and proposed a change of focus for designing the prototypes:

<u>The initial brief</u>

a) The base program works well, we will be refining certain parts of it.

b) Retention rates in tricot research are high, but we would like our users to be more engaged.

c) The basic feedback system works, but we would like to improve the model to allow for better feedback from the users.

d) We should try to engage farmers by adding gameful elements.

<u>Summary of the challenges</u>

1. Inconsistent dissemination of information: information is spread unevenly amongst potential participants.

2. Poor usability of user-facing forms and resources: form design needs improvement. Participants struggle to understand how to fill in the form when the time comes, possibly due to too much time has passed since its initial explanation. This may result in participants not filling the form at the right time and participants relying on others to fill the form for them.

3. Farmers don't seem to find much value in the research results: participants do not seem to emphasise knowledge of seed variety as being an important takeaway. The results sheet does not present the information in a fun or interesting way. Participants are unhappy with not having information on marketing the crop.

4. Participation rely on extrinsic incentives (such as learning, input provision, expectation, expert interaction, and community interaction).

A more narrow focus on what to design makes sense. The team explored different ways to redesign the tricot approach ranging from high-level service design to form design. The initial brief offered opportunities to work on multiple levels, however, the scope of the project and time available to the team, restricted us from moving in too many directions. Therefore, early in the process, it was concluded that a complete redesign of the methodology was not feasible (nor asked for in the brief) and that only certain subsections could be improved upon.

We decided to save the higher-level service design for a future opportunity. This means we omitted clusters 1 and 6 We also omitted cluster 9 as most of our focus until now lied on improvements that would directly impact the end-user experience.

Rebrief

We want to focus prototyping around:

- Expectation setting
- Empowering farmers to fill in the forms correctly

This allows us to assess where the major gains lie in building and field-testing prototypes in our context in a short time (with direct results). With tricot being a citizen science-inspired approach delivering on the learning outcomes becomes even more important. We, therefore, had a hunch that improving the feedback mechanisms and looking for alternative ways of communicating the results of the trials would be important.

Citizen science applied in agricultural research aims to support more efficient and less-labor intensive forms of data collection while at the same time increasing learning opportunities for participants and their wider communities. The voluntary nature of citizen science research also ensures greater social accountability towards participants in terms of feedback and knowledge sharing. Experiences in citizen science showed that user interfaces have a deep impact on the quality of the results that participants can generate. To live up to its characteristics of providing useful learning opportunities to participants also the format in which results are shared back to participants needs to be of high quality as it serves as an alternative user interface.

The project goal was to prototype and test new, playful, and more engaging forms for farmer participation in agricultural research. We wanted to gain insights on how interaction design can make data collection and results sharing a more engaging process for farmers. My research aim is to understand how designerly approaches can be successfully applied in a co-design setting including farmers early on in the design process.

Taking all things into consideration, information and feedback delivery should be our first point of improvement. Therefore the question guiding the design process will be:

How might we set up consistent information and feedback delivery Throughout the research process to deliver on expectations and motivations of participants?

7.7 Prioritisation of design ideas

We prioritised the following five design activities:

7.7.1 Develop a clear value proposition

Focus on expectation setting by offering participants a clear value proposition of why they should participate. This should not only focus on their responsibilities but more so on their benefits. Both direct benefits where participants learn about the first-hand experience with new varieties of crops they already use, as well as the benefit of learning about a range of varieties without having to test all of them themselves. The so-called 'wisdom of the crowd' principle should offer a clear benefit to participants, however, this message is often not emphasised enough. One way of doing this is through the establishment of a social contract. A practice that is recently pushed for by donors and research organizations. Since this can be a lengthy process to establish and agree upon terms of research with communities, it is not something that can be implemented at scale. From an ethical perspective, this should not be an argument for the omission of this step, however, in practice, this is often the case. Therefore, we would like to explore alternative (and perhaps simpler) ways of ensuring that all those involved understand their responsibilities and expectations are managed.

7.7.2 Redesign of data collection formats

Jonathan and Naoimh were interested in prototyping the 'observation card' after getting more insights into the tricot approach. They noticed that different forms were used in different geographic locations and that there was no set standard for creating the forms. This resulted in questions being asked in different ways, which could affect data quality. They were interested to explore whether we could use prototyping to get solid data about what forms worked well in these particular environments. Redesigning the existing data collection formats presents a low-hanging fruit as it creates an opportunity to evaluate if a process of rapid prototyping using form design is feasible within our context. Furthermore, being able to go through a quick round of prototyping offered valuable lessons in how to conduct prototype evaluation activities with farmers in rural Kenya.

7.7.3 Feedback mechanisms

Feedback mechanisms for end-users consist of two elements: feedback delivery and communicating the results of the trials. For feedback delivery, we looked at ideas to be able to deliver continuous feedback on participants' progress, build in intermediate data collection points rather than all data at the end. However, since this required a higher level service design of the research approach, this did not seem attainable in a short timeframe.

It is part of the final touchpoint in the tricot service journey in which results of the trial are shared back with the participants. Currently, this final touchpoint is skipped in some implementations or participants only receive the feedback sheet. It is important to give meaningful results back to the participants for ethical reasons (participants should receive information on the results of the trials as they were part of the research process) and to be able to deliver on the learning outcomes of the approach (participants contributed data to receive data from other participants and learn about the performance of all varieties included in the trials. Improving the delivery of results back to participants is therefore one of the key elements needed for improving feedback mechanisms.

7.7.4 Knowledge sharing activities

We also looked into alternative ways of offering feedback on the results of the trials. The participants from our study are smallholder farmers living in rural communities who generally disseminate and discuss information orally. Therefore, we looked into activities that would facilitate participants to share their knowledge and results in other ways than on paper. We want to find out which group activities would offer learning opportunities, which ones would be easy to use without heavy facilitation, and which activities would be perceived as enjoyable. We also want to learn about the process: how easy is it for the field staff to implement these activities? And what tools and visual aids provide the best results to facilitate the discussion.

7.7.5 Graphic literacy

As an additional activity, we wanted to test the ability of participants in reading and interpreting graphic representations of the data. It cannot be assumed that all users effortlessly read and understand all sentences, symbols, and data visualizations.

7.8 Discussion

7.8.1 Precedent study

In this chapter, we set out on a precedent study to identify useful ‘reference material’ that we can bring into the ideation and prototyping phases of the design process. This reference material was collected to inspire innovation. Rather than studying worked through solutions from our field of action, we looked for references outside the scope of the study yet offering similar features to its users.

Researchers would not normally look at a wide range of reference material in fields other than their own. Instead, their attention would be focused on following the ‘standard operating procedures for a specific method, applying them, and reflecting on the experience, with incremental innovation taking place after implementation. New method development often aims to optimise an approach, and designers then will ‘reference’ existing methods as a justification for the new method: *previously people have tried this, but this has the following shortcomings. Therefore we try this...* Analyzing previous methods and literature helps researchers justify the design choices they make. However, these references are usually only looked at informally and not made explicit in the development process.

The difference with a precedent study is that the reference material collected is not systematically analyzed but rather used as inspiration by highlighting the features that the designer might find interesting. Precedents are visual outputs that look more like a mood-board or a display used for reference during the process, rather than a study carried out at the start of the process. Often precedent is studied at various stages in the design process. At the fuzzy front end, it kickstarts the thinking process and allows designers to reframe their thinking by incorporating insights from other fields. At other times it might inform the design process during ideation, prototyping, or evaluation. As such precedents could also become part of an iterative process taken through various rounds of scrutiny and looked at from different angles.

The second difference in the information is that precedent can be 'manipulated' or extracted for the purpose at hand. It is not meant to be scientifically correct. Precedents as such are often not explicitly referenced. For example, in his article on 'the collections designers keep' Keller *et al.* (Keller *et al.,* 2006) indicate that collecting and organizing images, product ideas into collages helps designers deal with their design problems better and become more aware of the different design features. Experienced designers have a 'collection of reference materials available at any time during their career' and draw inspiration from this collection in different design processes. A precedent study therefore can become more of a personal endeavor than an activity in a single design process.

7.8.2 Ideation

In this second step of design synthesis, I described the sense-making process of the design team by drawing inspiration from Kolko (2011). Design synthesis forms the 'muddy middle' between the discovery and the design phase. It brings together the research with the designs we create. However, more often than not we are so excited about designing or prototyping new services, we forget all about the insights that the research brought forward (Kolko, 2011). Documenting the process of prioritising and distilling a design rationale or recommendations helps us make visible how the process took place.

7.9 Reflections

Each of the different team members conducted their own search for examples of large-scale user involvement and providing feedback to users. This led to a wide variety of examples from different fields, as each team member interpreted the task differently. What they do seem to have in common is that most of the examples are slightly authoritarian in nature. This implies that these examples all have a component that persuades people to do what we want them to. This was not an intentional choice; however, this might have affected our design choices in subsequent stages in the design process. It might indicate a persistent researcher bias: how can we get participants to do the tasks we want them to do (and then make it fun). This issue is further addressed in the discussion chapter.

7.10 Conclusions

Whilst normally not an explicit output of a design process, here I chose to share the collection of precedents to illustrate this step in the design process as several features that were represented here were used during the generative stages of the design process. Collecting and organizing the precedents helped us in three ways: (1) to get a better idea of the problem space and how other fields have tried to tackle barriers to participation in terms of engagement and communication (2) creating visual outputs or mood boards provided an excellent opportunity for each of us as part of a team with different expertise and backgrounds to convey our message and to show others what specific features we noticed and for what reason they took our interest. And (3) through the exercise of collecting and organizing (or grooming) precedent and drawing up the collages we became more aware of the form, function, and meaning of each of the examples and how these aesthetics and design features could be helpful design knowledge for us in terms of solving specific problems.

Similar to the representation of the precedent study, under normal circumstances, it is unlikely that the development and prioritization of ideas would be prominently featured in written reports. However, I chose to document the process here as it constitutes a necessary step in our design process; getting from the discovery and research phase to the phase where we start designing our solutions. I hope to show that it is not a completely ad-hoc process but grounded in a sequenced process where several activities combined, inform the design choices. Furthermore, there is value in documenting a design process. As in any standard ideation process, many ideas were brought forward and yet only a few were chosen as inputs for the continued design process. Having a record of which choices were made and how they choices were made, might inspire other design processes.

Chapter 8

Rapid prototyping

8.1 Introduction

I assess the feasibility and usefulness of rapid prototyping within a farming community setting in a developing country and explore the implications this might have for the design process. We explored a form of *rapid prototyping* where the users are involved in the evaluation of early developed prototypes (Bødker and Grønbæk, 1990, 1991). The prototypes are intended to act as artifacts to explore the benefits and constraints of involving participants early on in the process. They are designed to answer the following research questions:

Question 1 (subjective level):
Can we make the processes of data collection and results sharing in tricot research more engaging for participants?

To answer this question, we aim to build prototypes and field-test them with actual users. We use a process of rapid prototyping to generate quick insights into the needs and wants of the users regarding analog forms for data collection and feedback delivery. The aim wasn't to create high-fidelity prototypes, however, the insights generated throughout the process in terms of prototype development and user requirements are reported here for further use.

Question 2 (meta-level):
How might we use designerly approaches to involve rural farmers in the design process?

The prototypes were intended to test the feasibility of redesigning data collection and feedback delivery formats with inputs from actual users. We went through a quick design process to design formats and activities we could test under field conditions.

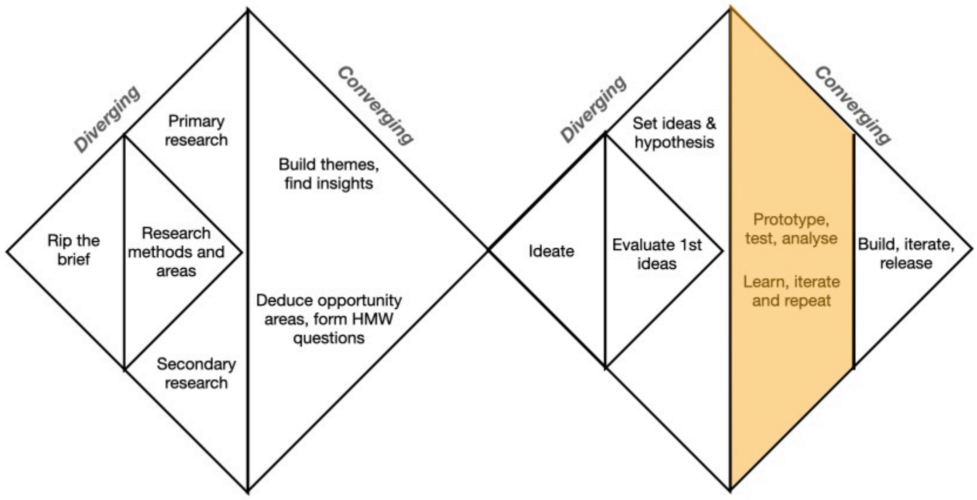


Figure 33: Stage 4 in the design process

Figure 33 visualises is the final stage in my design process, where we take the designs to the field for further prototyping and/or validation. The lessons learned either feed back into the design process to guide the design process or are documented for future reference. Building high-fidelity prototypes, products or services was not part of my Research through Design process.

8.2 Methods

The iterative process of designing prototypes consisted of building the artifacts used to explore user interactions in data collection and knowledge sharing and field testing these interactions. The insights collected during the field evaluation with users were used to adapt or rebuild prototypes in a subsequent round of design and testing. The design process took place over 8 weeks from 8 July - 30 August 2019. Field evaluations took place on 9-10 August 2019 and 15-16 August 2019.

8.2.1 Selection of participants

Participants were selected by lead farmers of farmer groups who worked with the NGO Lutheran World Relief in Eastern Kenya. Groups were intentionally kept small and varied from 6-8 participants.

8.2.2 Iterative design & rapid prototyping

We used a process of iterative rapid prototyping to evaluate alternative designs of data collection and feedback provision for the tricot approach. Rapid prototyping is a process of generating quick designs, usually with low-fidelity to obtain feedback and evolve the design further. For example, paper prototyping allows for fast iterations based on inputs from users (Snyder, 2003) and as it is relatively inexpensive it increases the likelihood that more ideas get tested. Prototypes can be used to explore design solutions, and in our case, they are not only intended to 'solve a problem' but more so to improve our understanding of a problem and how we should tackle it.

A process of rapid iterative successions of designing templates helps us to (a) better understand the problems in data collection and feedback delivery particular for/to tricot research, (b) explore alternative input mechanisms based on interaction design principles, (c) testing and validating our assumptions in how to design templates (e.g. Communication) for rural farmers, and (d) how to solicit inputs in the design of these templates using UX field evaluation principles.

Setting aside a limited amount of time in the front end of the design process, prevented the 'overdevelopment' of the prototype designs. As Tim Brown (2008) mentions: "*Prototypes should command only as much time, effort, and investment as are needed to generate useful feedback and evolve an idea*" (pg 87). It is easy to become too invested in an idea when we spend a considerable amount of time in its development. When I look back at my own experiences in survey design, we would spend a few months compiling a questionnaire covering the topics we intend to explore. When it was time to implement the survey we would field test the questionnaire directly with users, or with the enumerators responsible for collecting the data from the users. We were usually left with little time or incentives to change the design of the survey and other than correcting spelling mistakes or changing the wording of a specific question, no real changes were made. If we had spent more time field testing the survey, we might have come up with a different list of topics to explore or even an alternative way of administering the questionnaire more sensitive to the context in which the survey was implemented. Providing users with the early versions of the questionnaire design would have ensured that these insights are taken on board as part of the design process, not as a validation of our efforts at the end of the design process. Taking this into account, we presented our participants with unfinished low-fidelity paper prototypes and knowledge-sharing activities. Low fidelity prototypes are likely to solicit more inputs from users as they can see room for improvement. Here we wanted to test whether an idea would contribute to the improvement of data collection and feedback delivery on the results in the tricot approach. When a prototype looks too polished, people might be hesitant to critique the actual design or intention and focus on minor issues such as grammar or color use (Snyder, 2003, p.58). Furthermore, the 'show, don't tell' principle helps to visualise our ideas and allows for shared communication through prototyping. Because farmers, researchers, and development agents often do not speak the same language. By sketching it out, you can create a common understanding of the goals (Warfel, 2009).

We used the following suggestions in our designs:

1. Exploring a range of different approaches first which we test by making prototypes first before preferring one method above the others. Test out many ideas (knowledge sharing!)
2. Fast iterations to avoid 'falling in love with our prototypes'. A quick succession of lo-fi prototype testing didn't allow us to overly invest in one of them. Also, teamwork helped here!
3. We want to create a model of *how* it could work, not an actual working version of a feedback delivery session. Therefore we did not need to test the whole thing, but we could test it in pieces covering many different ideas. We were not simply asking for approval from users, we were using the variations in design to test which provide the best results (in terms of preference, learning, time, and resources).
4. Our aim is not to create the perfect data collection sheet or the perfect feedback format. We aim to see if designerly approaches such as prototyping and user evaluation (UX) work for our intended audience. And what the benefits of a more explicit design are or the constraints of field testing might be.

The rapid prototyping process took place over eight weeks. The first two weeks were used to immerse the team into the case study in terms of geographic location, user context, research approach, and current designs. Week three and four were used to collect precedent and design prototypes. In weeks 5 and 6 the students traveled to Kenya and the team then convened in Nairobi to prepare for the field evaluation, conduct the field tests, reflect on the process and redesign the prototypes. The last two weeks were used to write a report reflecting on the prototyping process and creating annotated design documents.

8.2.3 Field evaluation of prototypes

Several types of prototypes were developed for field testing: prototypes for data collection, feedback delivery, group knowledge sharing, and a graphic literacy assessment. At the end of each field testing day, the team reviewed the process and collected insights, both individually and as a team. Field notes contained comments and insights on the process as well as on the insights generated through the interactions of participants with the prototypes. After the first field evaluations, the design team reviewed the prototypes and built new or adapted prototypes.

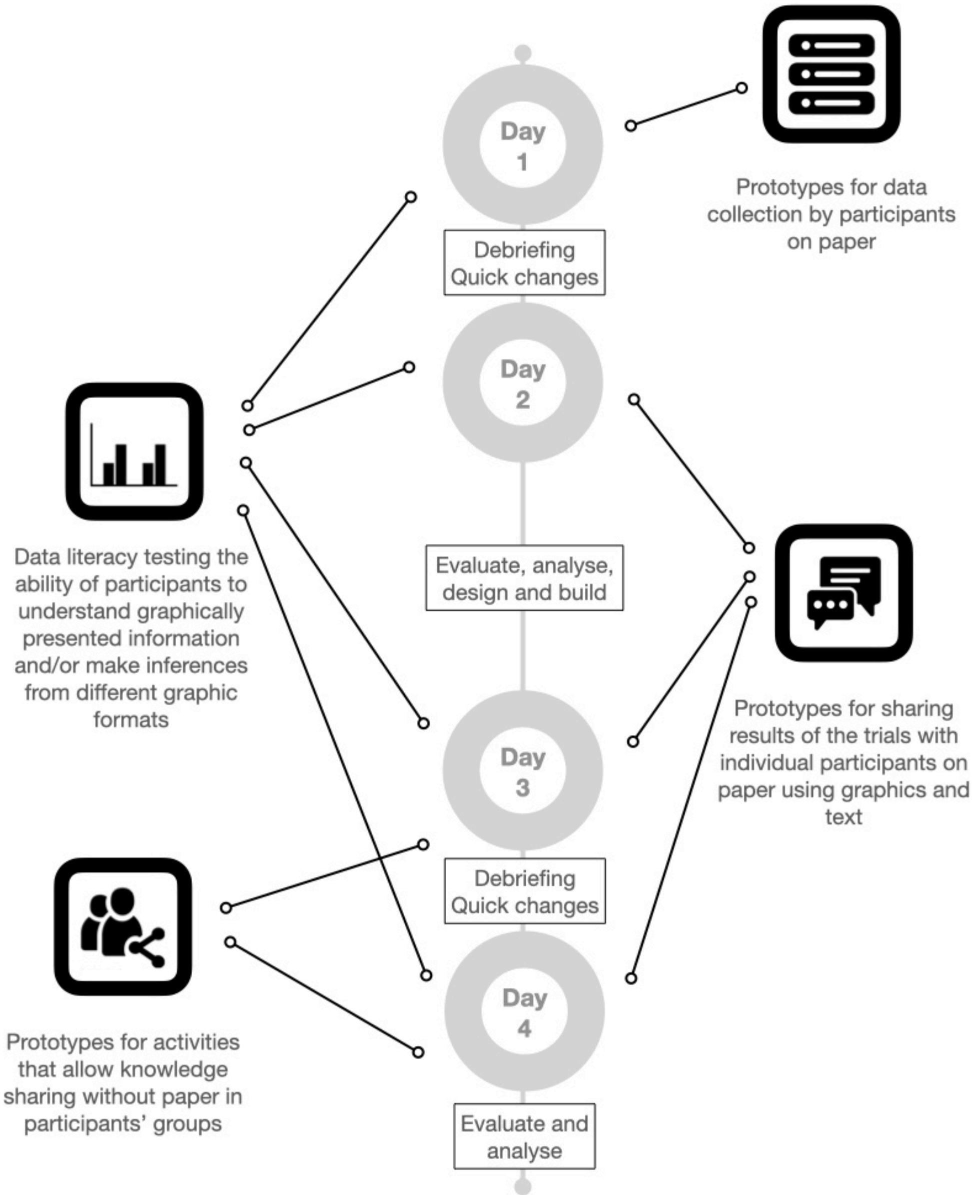


Figure 34: Timeline of prototyping activities

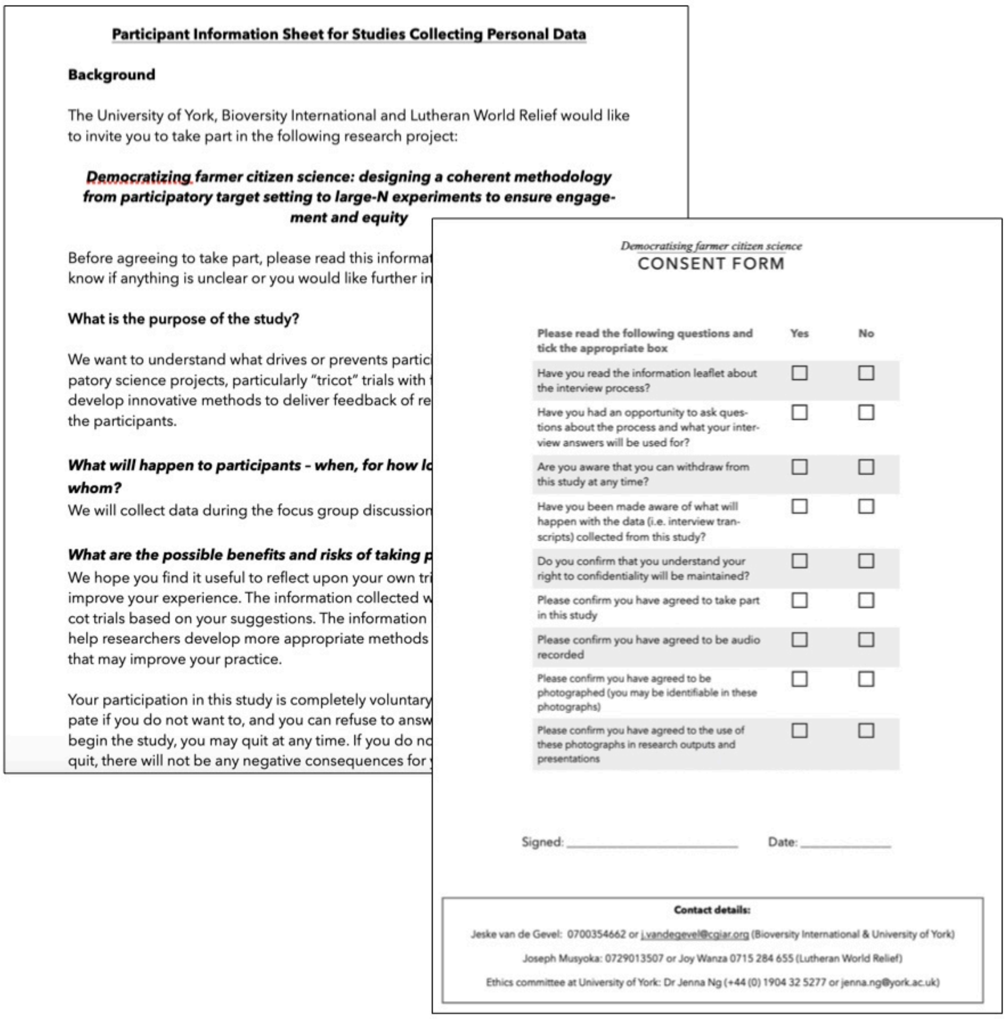
The field evaluation consisted of two consecutive co-design sessions with two groups of farmers. Researchers from the United Kingdom, the Netherlands, and Germany were aided by local facilitators from the NGO Lutheran World Relief in carrying out the field evaluation. Each session lasted around three hours and contained the following activities:

Beginning the workshop

The field evaluation sessions took place on various farms of participants. The host took the time to show us around his or her farm. We then sat down to start the activities. After formal introductions, we explained the purpose of the activities planned for the day.

Taking informed consent

The first step of taking informed consent is reading aloud the participant information sheet. An example of the participant information sheet and consent form is available in appendix 2. The field officer read the participant information to the group of participants who were each given a consent form to sign. The field officer reads a part in English, followed by a translation in the local language.



Participant Information Sheet for Studies Collecting Personal Data

Background

The University of York, Bioversity International and Lutheran World Relief would like to invite you to take part in the following research project:

Democratizing farmer citizen science: designing a coherent methodology from participatory target setting to large-N experiments to ensure engagement and equity

Before agreeing to take part, please read this informat
know if anything is unclear or you would like further in

What is the purpose of the study?

We want to understand what drives or prevents partic
patory science projects, particularly "tricot" trials with
develop innovative methods to deliver feedback of re
the participants.

What will happen to participants – when, for how lo
whom?
We will collect data during the focus group discussion

What are the possible benefits and risks of taking p
We hope you find it useful to reflect upon your own tri
improve your experience. The information collected w
cot trials based on your suggestions. The information
help researchers develop more appropriate methods
that may improve your practice.

Your participation in this study is completely voluntary
pate if you do not want to, and you can refuse to answ
begin the study, you may quit at any time. If you do no
quit, there will not be any negative consequences for

Democratising farmer citizen science
CONSENT FORM

Please read the following questions and tick the appropriate box	Yes	No
Have you read the information leaflet about the interview process?	☐	☐
Have you had an opportunity to ask questions about the process and what your interview answers will be used for?	☐	☐
Are you aware that you can withdraw from this study at any time?	☐	☐
Have you been made aware of what will happen with the data (i.e. interview transcripts) collected from this study?	☐	☐
Do you confirm that you understand your right to confidentiality will be maintained?	☐	☐
Please confirm you have agreed to take part in this study	☐	☐
Please confirm you have agreed to be audio recorded	☐	☐
Please confirm you have agreed to be photographed (you may be identifiable in these photographs)	☐	☐
Please confirm you have agreed to the use of these photographs in research outputs and presentations	☐	☐

Signed: ______________________ Date: ____________

Contact details:
Jeske van de Gevel: 0700354662 or j.vandegevel@cgiar.org (Bioversity International & University of York)
Joseph Musyoka: 0729013507 or Joy Wanza 0715 284 655 (Lutheran World Relief)
Ethics committee at University of York: Dr Jenna Ng (+44 (0) 1904 32 5277 or jenna.ng@york.ac.uk)

Figure 35: Informed consent for prototyping study

The participant information sheet explains the purpose of the study and the activities taking place. It explains that participants are free to opt-out of the process at any time and that none of the data is used than otherwise stated in the document. We also ask for permission to collect audio recordings and photographs which we will use in the publication of this study.

Evaluation of prototypes

Prototypes for data collection and prototypes for feedback delivery were evaluated in four evaluation sessions. Steps in the process:

- Observation of form completion: Observe the participant filling out the observation card, taking notes of their actions, and prompting them to think aloud as they do so. Two people observed two participants filling out the form, one to prompt and another to take notes. Duration: 20 min.
- Participants explain forms to each other: Two participants with different versions of the forms explain how to fill it out to each other, showing us their understanding and gaps in their knowledge. Duration: 10 min.
- Read back: Read back and explain how the form was intended and verify if this matched their expectations of the form. Duration: 20 min
- Group Discussion: The group of eight participants discuss what they liked and disliked about the two forms, and ways to improve them. Duration: 20 min.

We had initially planned a redesign activity where participants were given elements of a form that they could freely rearrange or use to suggest improvements. This activity was skipped during the workshops due to limited time. Instead, insights were collected during the group discussion and it felt tedious to repeat it using paper.

Figure 36: A translator helping participants interpret feedback forms during field testing

Figure 37: Comparing prototypes during field testing

Figure 38: Group discussing different feedback formats during field testing

For the knowledge-sharing activities, we tested different activities where we varied the playground. For example by asking participants to go to a designated space or asking them to come in front of a group to place marbles in jars or sit down in a circle to discuss the results. We also varied the level of facilitation by asking participants to answer questions or choose to tell a story from their own experience. We alternated between knowledge sharing and knowledge generation. We used different visual aids to prompt participants to contribute to a certain topic.

Graphic literacy was tested with individual participants in a face-to-face interview. We asked participants to look at a set of eight visual representations of locally relevant data and interpret the graphics. We presented the graphics to the participants and told them that this is an individual effort and they should try to answer the questions by themselves before asking for help. We asked them to look at the graphics one by one and gave them a minute to make sense of the graphic. Then the researcher prompted the participant with 3-4 questions related to the graphic. If they needed help or couldn't answer the questions within 2-3 minutes we marked the question as wrong.

Debriefing (group discussion)

During the debriefing, feedback was shared on the process and the insights generated during the session. It was used as an open space for researchers, translators, lead farmers, and participants to share their thoughts and concerns.

8.3 Redesigning data collection formats

8.3.1 Current design

Existing data collection formats, in itself the result of multiple iterations representing insights collected by researchers and field staff during the implementation of tricot, were taken apart by the two design students. Noticing a lack of consistency in data collection formats between applications of tricot across different geographic locations, they wanted to gain insights on what elements regarding form design work well in rural farming communities and how researchers with limited resources go about making the forms. The design team had access to different data collection templates that offered a good starting point to use these differences in form design to create prototypes.

The current methodology for data collection had the following characteristics that we wanted to retain:

- Low literacy or research skills are required to complete the form.
- Low on-site supervision is needed to complete the data collection.

As part of the tricot, trial package participants receive three different technologies, a brochure explaining the process, and a data collection form called the 'observation card'. Technologies can consist of seeds or seedlings of different plant varieties or planting techniques, for example. The observation card is kept by the participants throughout the entire growing season, and should be filled out at different intervals (f.e. After the plant germinates, after flowering, and after harvest). The observation card helps participants in their observations, specifying a time to go to the field to compare the different technologies and specifying which traits or plant characteristics they need to observe. It simplifies the ranking by 'forcing' participants to choose between the three different technologies. After the season is completed, field agents will visit the farms to collect the data in a mobile application. Participants can keep their observation cards with them for future reference.

An observation card is an important tool in the tricot research process supporting (guiding) the experimental process of the participant. In most cases, participants of tricot experiments do not receive training on how to perform the trials other than explaining the process of making observations and collecting data. If any instruction is provided, it is concise due to the scale on which tricot operates. Therefore the observation card needs to be able to support the process of making observations, planting and collecting data, be user-friendly, and be self-explanatory. The form should include nudges to make observations at set times during the growing season and for participants to complete the data collection formats without external help.

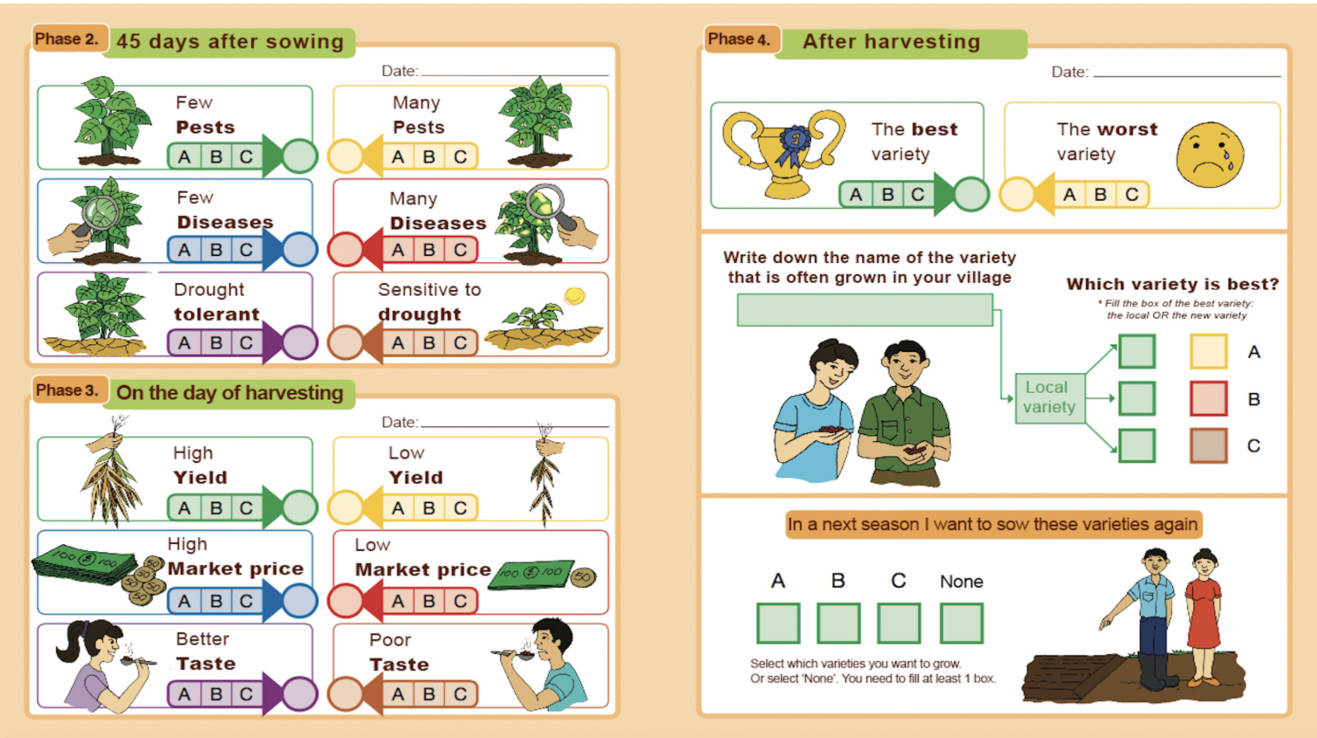


Figure 39: Example of a data collection format for tricot trials (source: Bioversity International)

8.3.2 Design choices and explorations

The team explored several ways to redesign the data collection forms. First, we took apart the existing forms and compared existing data collection templates used in the tricot approach, to see how input methods or use of graphics and symbols differed and how this might have affected data quality. I present a few examples of the elements we experimented with. This section is adapted from Murchan & Skjöt's annotated designs. The full document is included in appendix 3.

Standardised templates

One of the issues we came across is that researchers are left in charge of designing the data collection format based on the unique properties of their tricot implementation. There is no set template that they can use. Without a full understanding of the tricot research process and the underlying ideology, this could result in data collection templates that are incompatible with the platform used for online analysis (climmob.net). Similarly, a lack of experience in designing good forms could result in user-unfriendly data collection formats. Can more prescribed form design help to prevent these issues? Several ideas were considered:

1. Create an online template creator where researchers can 'drag and drop' different elements to compile their data collection templates.
2. Creating data collection formats that are provided to participants in tricot research at set times throughout the growing season to nudge them to collect data at the right time.
3. Test different paper sizes and types. Consider the quality of the paper. If we ask participants to carry the forms to the field when making observations, it might be better to add a plastic cover or use heavy coated paper.
4. Do the graphic features and icons appear legible when printed using a grayscale.

Input method

The team redesigned the input format from making a 'forced choice' to ranking. An often-used input system in the original data collection formats required participants to fill one of the letters ranging from A, B, and C into a box. Here they rank the letters A, B, and C from worst to best.

Figure 40: example of a input format design

A few different layouts were created to see which is the most intuitive to fill out. In the original forms checkboxes for two different questions were conflated into one or had the inputs very close together, causing potential confusing on which checkbox to use.

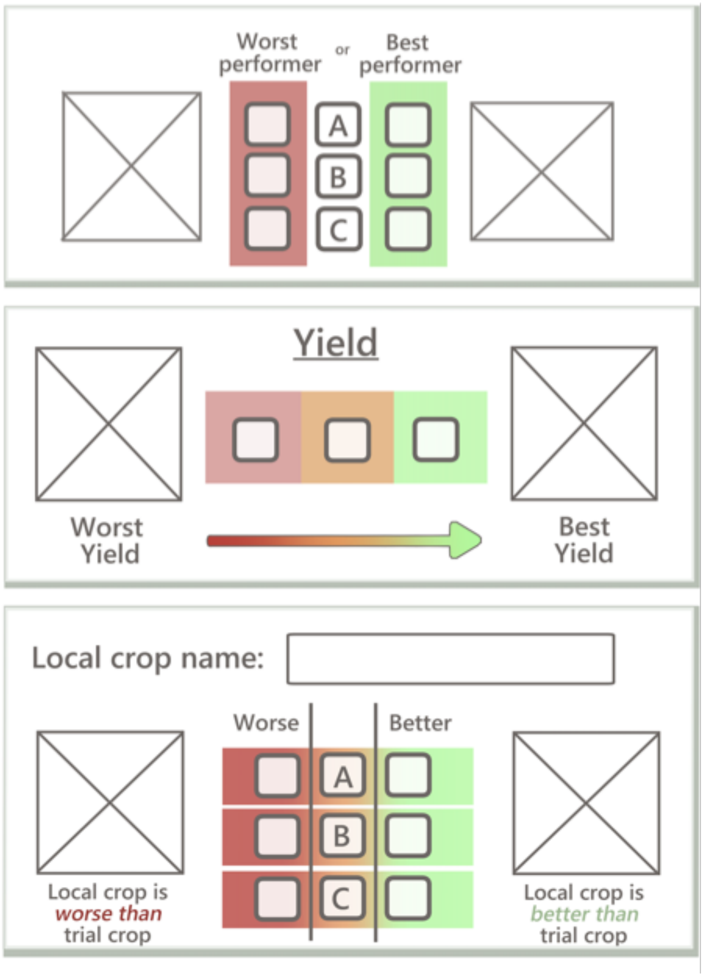


Figure 41: example of different input mechanisms

The team wanted to experiment with checkboxes that were clearly separated, yet still have a sense of relatedness between them. This resulted in trying to tie things together using visual elements like an arrow.

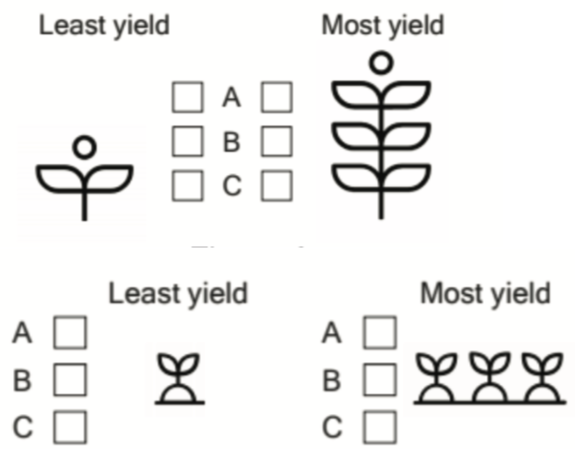


Figure 42: examples of input formats in black & white

ABC paddleboards were used to add a graphic element to the questions. Since participants are ranking three different crop varieties, each variety would get a different paddleboard labeled A, B, or C. These paddleboards are displayed for each following question. This was a way to create a 'forced choice' for worst performance and best performance. If you know the worst and the best then you automatically know what lies in the middle as well. This principle only works because tricot limits itself to evaluating 3 crops. This aids the data analysis and simplifies the evaluation exercise for participants.

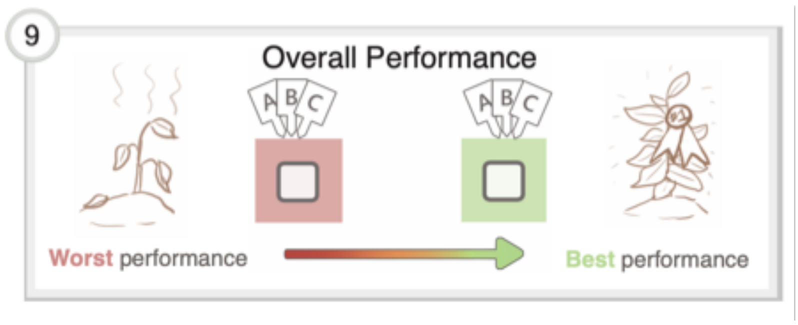


Figure 43: Using paddleboards

Another input method for which we created a mock-up was drawing lines between the letter using ticks and asking participants to fill a cross for the 'worst' option and a tick mark for the 'best' option. However, this seemed to overcomplicate the input mechanism and is prone to misinterpretation both by the participant as well as the person inputting the data at later stages.

Another input method we conceptualised was using colored pens to mark the best and worst crops, using some of our color focus from earlier. This is more resource-intensive and relies upon the participants reliably looking after these resources as they visit their experiments throughout the season, e.g. They would have to keep both pens handy.

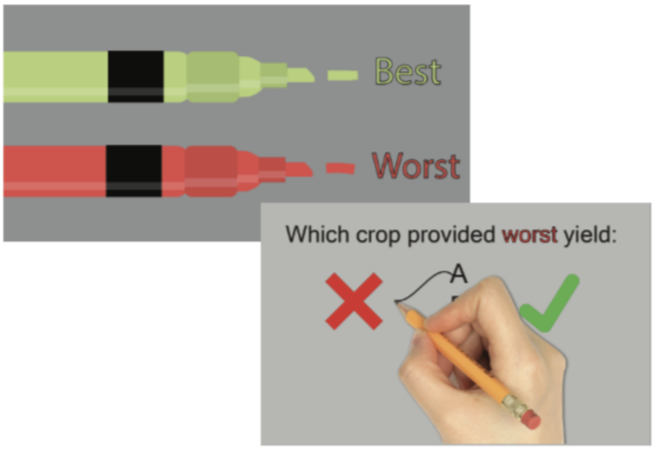


Figure 44: Alternative input methods

Colour Use

In the design process, we looked at including color to enhance the clarity of the questions. The team wanted to test if using green and red for positive and negative associations are perceived similarly in our context. Some considerations were given to make the icons understandable and readable to color blind individuals and when printed with black and white printers.

Icons

The use of icons was part of a long debate on whether we should be able to provide customizable icons to researchers who create the data collection templates, how much ink is used on graphics versus conveying information, and if we should opt for realistic icons rather than abstract icons. We can't assume that different icons or pictograms are interpreted the same by different users. Researchers might have a different understanding of what a certain icon represents than participants do. It is worthwhile to test this assumption under field conditions.

The original forms were created as part of projects running in Latin America and the icons created have been passed on to other project teams elsewhere. Custom icons were created for the forms representing African culture and crops. Custom icons are easier to tailor into project-specific meaning and needs.

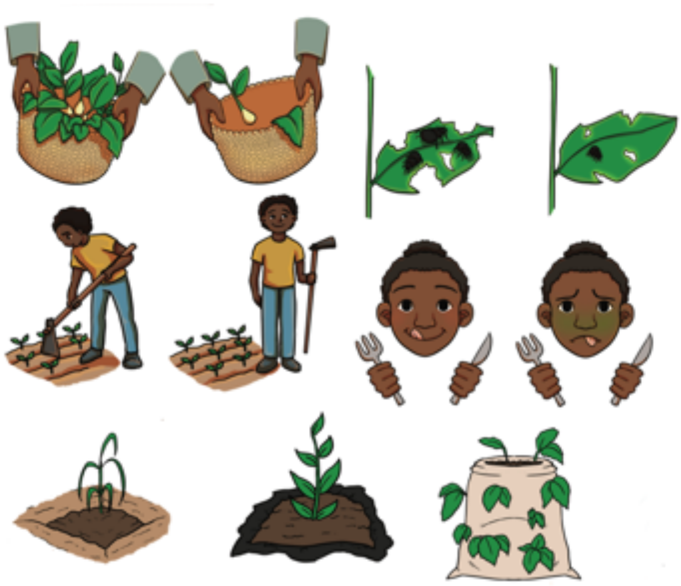


Figure 45: Customised icon set (illustrations by Naoimh Murchan)

Instructions

The original forms folded like a brochure and the instructions as well as the contact details of the research team were printed on the back. The team introduced the instructions on the front page before any of the questions, showing the participant how to fill the form.

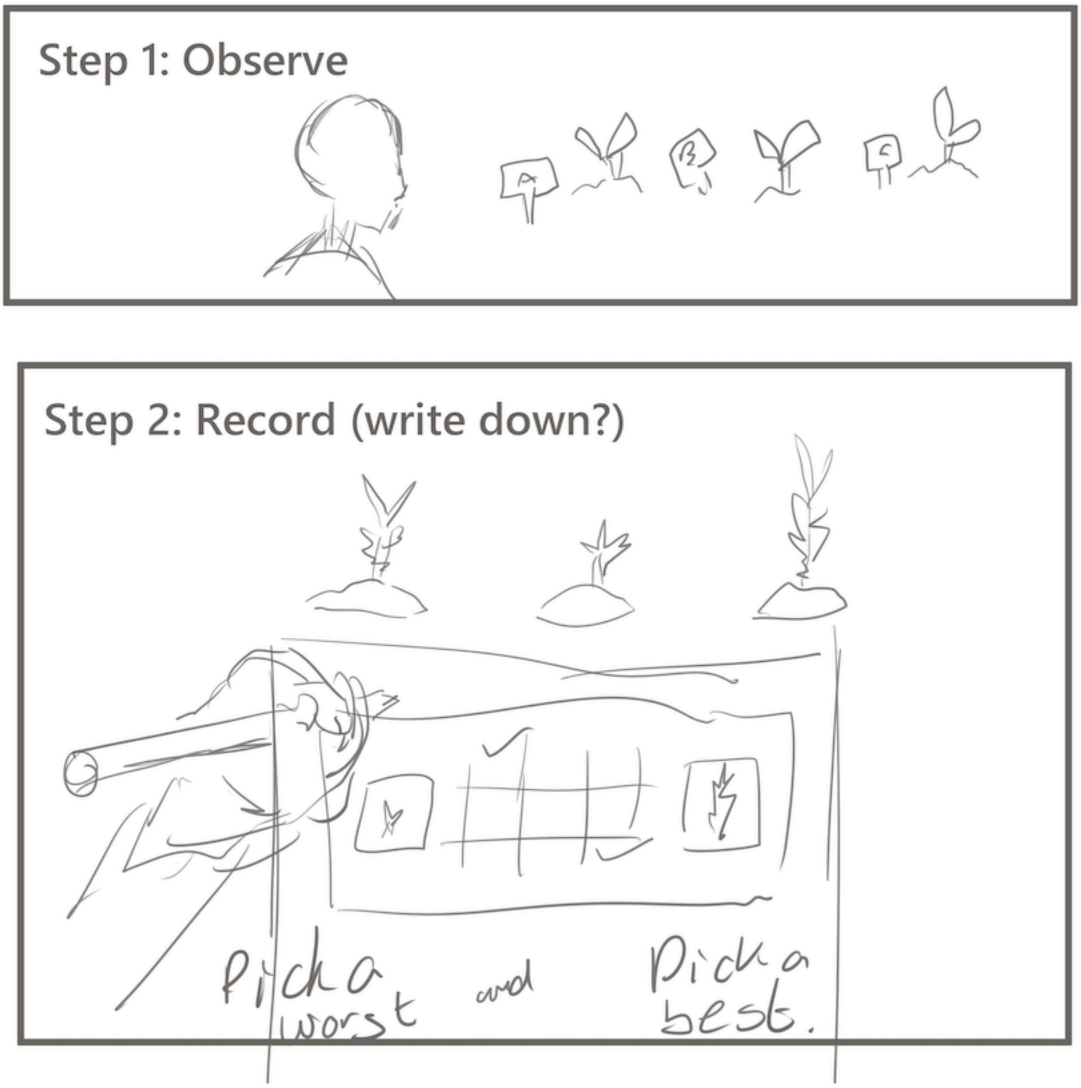


Figure 46: Exploring different instruction formats (illustration by Naoimh Murchan)

Prototypes

We designed two alternative data collection formats to test under field conditions. The first format used a forced-choice input mechanism and color scheme and arrows to distinguish between least desirable traits in red and most desirable traits.

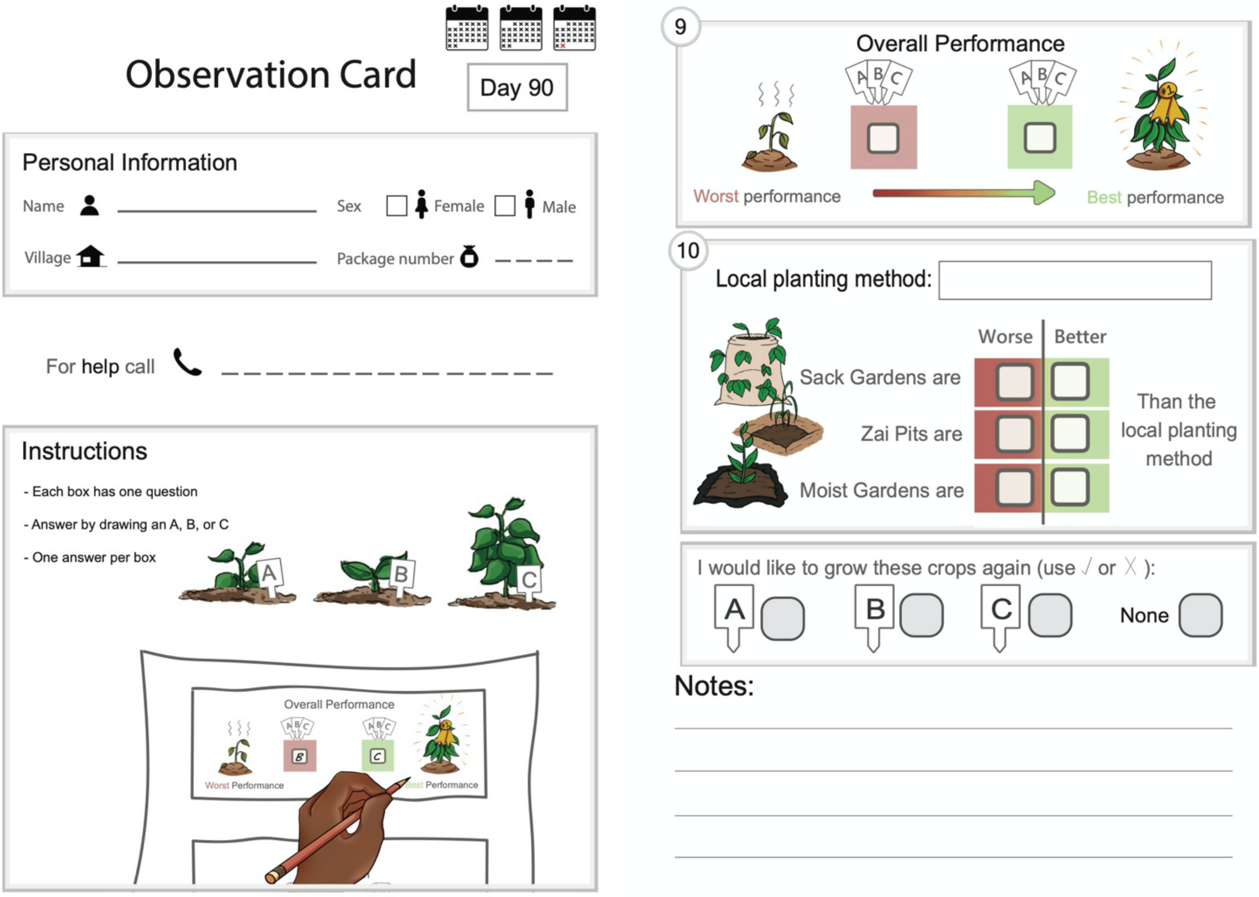


Figure 47: First prototype for data collection

The second format used separate questions to 'force' users to choose the least desirable trait and another choice for the most desirable trait. Furthermore, it compares the different kitchen garden types.

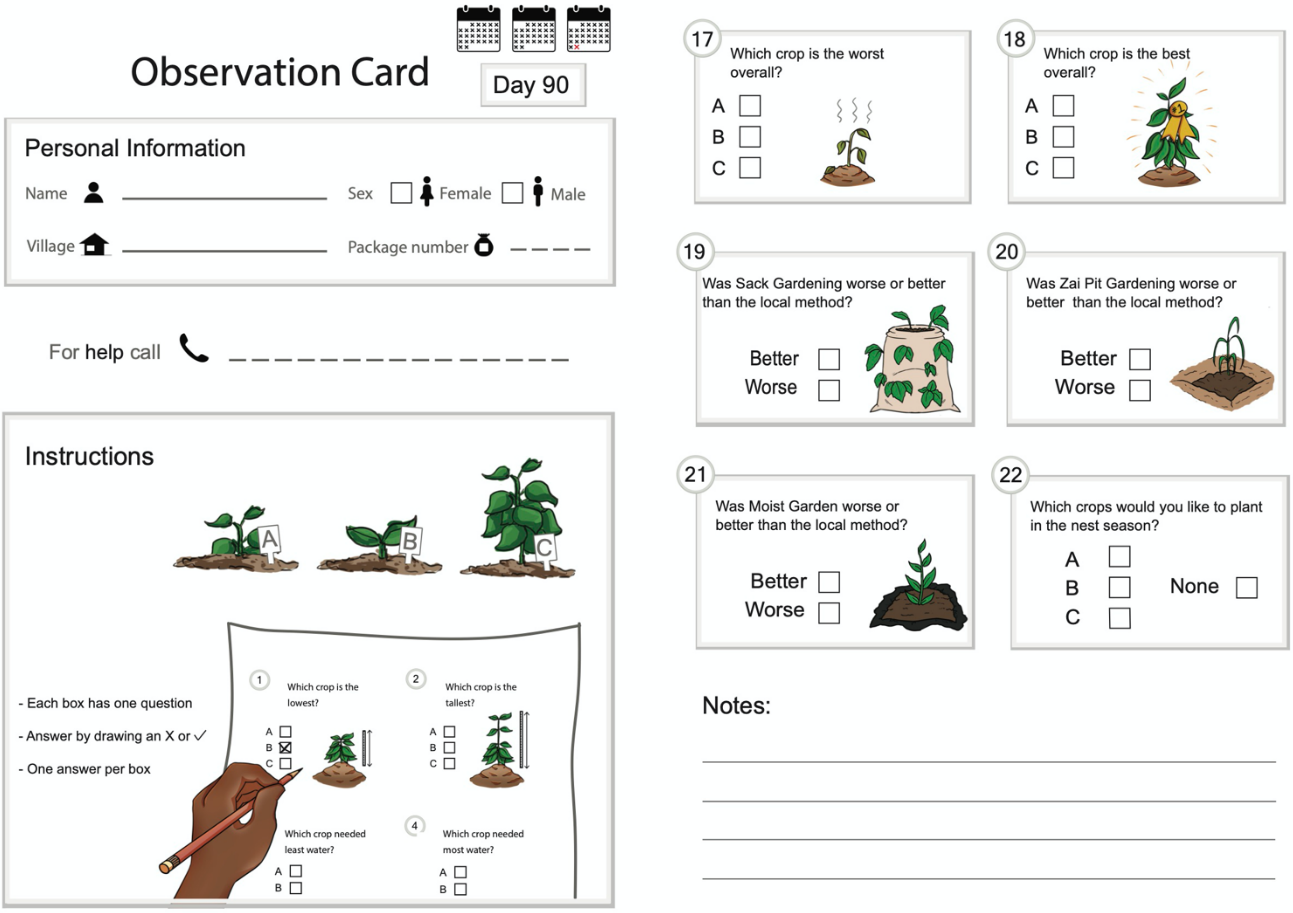


Figure 48: Second prototype for data collection

8.3.3 Activity description

Participants are handed different versions of the data collection prototypes and asked to sit in pairs as they explore the prototypes. The activity consists of the following steps:

1. <u>Observation of form completion</u>: Observe the participant filling out the observation card, taking notes of their actions, and prompting them to think aloud. Ideally, two people observing per participant fill out the form, one to prompt and another for note-taking. Duration: 20 min.
2. <u>Participants explain the form to each other</u>: Two participants with different versions of the Forms explain how to fill it out to each other, showing us their understanding and gaps in their knowledge. Duration: 10 min.
3. <u>Data interpretation</u>: In the initial Step 1 groups we read back through the form as we interpret it to see whether this is as they had intended. Duration: 20 min

4. Group discussion: The group will gather together, have some time to reread the two forms, before discussing what they liked and disliked about the two forms or any ways they can think to improve them. Duration: 20 min.
5. Redesign activity: Based on the ideas, opinions, and thoughts from the previous exercise, the group will be given a selection of cut-out pieces and parts from the original forms to rearrange and create their ideal forms. Duration: 30 min.

The major lessons learned are summarised below:

1. People do not attentively read the first page but often skip this part to go to the actual questionnaire.
2. Having several A4 sheets of paper stapled together poses a challenge under field conditions, rather have the questions using a bounded booklet.
3. Stick to a single mode of entering data, and do not switch from asking respondents to tick boxes and fill letters. This confuses the respondents.
4. Ticking boxes felt more intuitive for the participants in this study.
5. Separating the questions into best and worst traits increases the readability of the questionnaire.
6. Increase the font size and size of the icons and include fewer questions on each page, which helps to increase the readability of the questions.
7. Customise the questionnaire to the local situation. Invest time to include proper translations of the questions to pose them in the local language. Using a tailored set of icons that represent the experiment at hand in the most appropriate manner, limits misunderstanding of the questions.

8.3.4 Reflections on the process

Two different variations of a data collection format were tested with a group of potential tricot users. Participants are asked to help improve the data collection formats of a research project they are currently involved in. Their incentive for doing this is to improve the forms for their benefit as well as the benefit of the group of participants at large. However, the task at hand is abstract and doesn't provide enough direct incentives. Participants were willing to spend time on the activity, however lacked direct engagement with the task.

8.3.5 Moving forward

For future testing, more time should be spent in explaining the activities to the implementing staff and researchers. Role-playing the activities with the local facilitators beforehand or having a script they can use during implementation, will help clarify what is expected from them during the activity. For example, that they should not offer clarifications or 'help' participants in filling the forms, but rather get them to evaluate the formats and observe where the participants get stuck.

The observation and group discussion phases would benefit from a list of prompts to help extract useful data about the participants' experiences and encourage them to think aloud. It would help the local facilitators structure their observations.

The activity showed us that testing multiple forms is better than testing a single form and thus asking for improvement. Presenting users with multiple design options helps to create a discussion on preferences rather than seeking approval.

8.4 Form design for feedback delivery

Delivering meaningful feedback is an important part of the citizen science ideology. In successful tricot implementation, extension officers and field staff were able to organise meetings with the participants in small location-based groups to discuss the findings of their research and compare their results with other groups. This information has proven to be of value to users. However, this traditional form of participatory agricultural research can become resource and labor-intensive and might be difficult to achieve when scaling up the research to include large numbers of participants. To overcome this issue Bioversity has developed software that aids the researchers in the quick analysis and dissemination of the results. With a simple click of the button, researchers conducting tricot trials can generate 'feedback sheets' for each participating farmer. However, this feedback sheet provides limited information in a format that might not be suitable for its audience.

8.4.1 Current data compilation and analysis process

Here I highlight the differences between the suggested feedback process and an actual feedback process (see figure 49). The tricot guidelines prescribe three steps after participants have completed their trials: data collection and compilation in a single process, data analysis, and feedback on the data (results). In the final step, the designers of the approach suggest a collaborative evaluation of the trials in a final workshop.

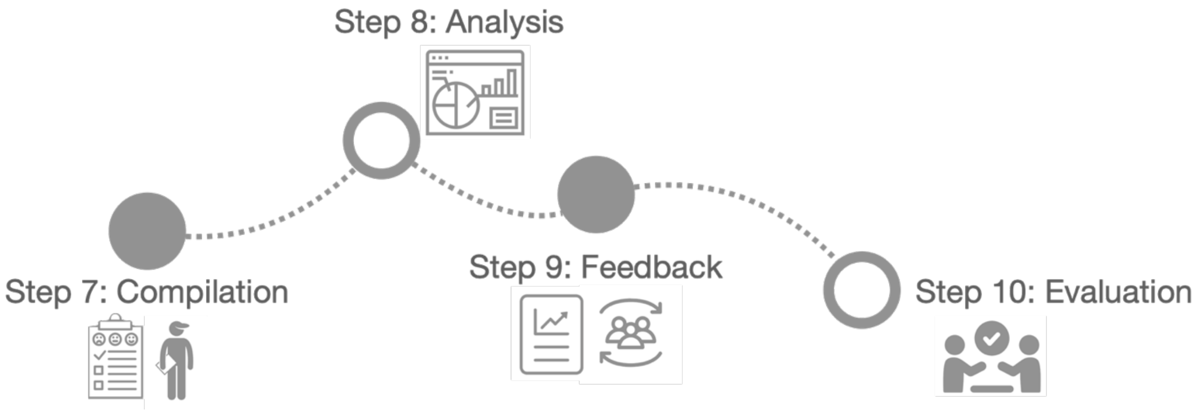
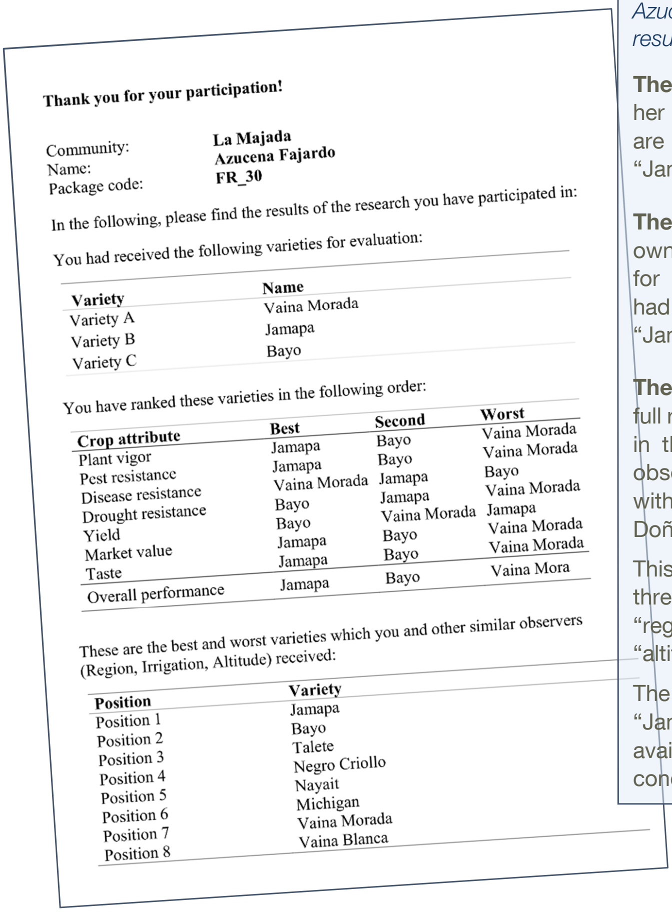


Figure 49: Steps in the tricot trial research process for data collection and feedback delivery

> Step 7: Compilation: the local designated field agents collect and compile the observation data from the tricot farmers, either in person or by phone. They record the information digitally and send them on to the implementing organization. For this, they can use the free 'ODK Collect' smartphone app, which is connected to the climmob software.
>
> Step 8: Analysis: the implementers compile and analyze the data from the trials, using the climmob online software, to identify which technology options showed the best performance and under which conditions.
>
> Step 9: Feedback: the implementers provide feedback to every participating farmer: the names of their three technology options, which options were most suited to their farm (out of the three options tried by them and out of all the options tried by farmers throughout the project), and where to obtain them.
>
> Step 10: Evaluation: Tricot is an iterative process: after every project cycle, researchers, implementers, and farmers collaboratively evaluate how the process may be improved in the next cycle.

Currently, the feedback output contains the name of the three crop varieties each participant received in their trial package and how they ranked each trait for these varieties. It shows how the new varieties ranked in comparison to the common/local variety. Last, it contains a list of all varieties included in the trials ranked according to the observations of all participants. See figure 50 for an example.

The information sheet


Thank you for your participation!

Community: **La Majada**
Name: **Azucena Fajardo**
Package code: **FR_30**

In the following, please find the results of the research you have participated in:

You had received the following varieties for evaluation:

Variety	Name
Variety A	Vaina Morada
Variety B	Jamapa
Variety C	Bayo

You have ranked these varieties in the following order:

Crop attribute	Best	Second	Worst
Plant vigor	Jamapa	Bayo	Vaina Morada
Pest resistance	Jamapa	Bayo	Vaina Morada
Disease resistance	Vaina Morada	Jamapa	Bayo
Drought resistance	Bayo	Jamapa	Vaina Morada
Yield	Bayo	Vaina Morada	Jamapa
Market value	Jamapa	Bayo	Vaina Morada
Taste	Jamapa	Bayo	Vaina Morada
Overall performance	Jamapa	Bayo	Vaina Mora

These are the best and worst varieties which you and other similar observers (Region, Irrigation, Altitude) received:

Position	Variety
Position 1	Jamapa
Position 2	Bayo
Position 3	Talete
Position 4	Negro Criollo
Position 5	Nayait
Position 6	Michigan
Position 7	Vaina Morada
Position 8	Vaina Blanca

With her information sheet, Azucena Fajardo now learns the results of her trial:

The first table tells her that her three varieties A, B and C are called "Vaina Morada", "Jamapa", and "Bayo".

The second table repeats her own evaluation. For example, for Overall Performance, she had ranked the variety "Jamapa" as best.

The third table presents the full ranking of all eight varieties in the project, based on the observations of all farmers within the same group as Doña Azucena.

This group is defined by the three explanatory variables "region", "irrigation", and "altitude".

The results show that "Jamapa" really is the best available variety for the conditions at Azucena's farm!

This is the information sheet for Doña Azucena.

Figure 50: Existing feedback formats (Steinke and van Etten, 2016)

In the previous chapter, it came to light that each of these steps was interpreted in alternative ways by the implementing organization. We can summarise the particular constraints for our context, and more specifically for feedback delivery in tricot, as follows:

- Feedback sheets are disseminated through communal workshops. How will participants receive the information if they cannot attend this workshop?
- Poor usability of user-facing forms and resources. Information is provided in a non-intuitive manner and is difficult to read.
- Participants don't seem to find much value in the research results either because they lack information on how to interpret and use the data that is provided to them or the fact that it is presented in a non-engaging format.
- Researchers are eager to collect the data, however, seem to have low accountability towards the end-user. This might limit the feedback provision as a whole. This is a

common issue in participatory agricultural research and participants might hold low expectations in terms of receiving (any kind) of feedback on the results.

8.4.2 Design choices

Improving the feedback delivery in tricot research is a key element in improving the learning outcomes for participants. The following improvements are recommended:

- Results are analyzed and translated into information that is digestible for its intended audience. The context in which the data is presented is clear to its users as is its value.
- Form design is used to optimise readability for distribution in low-literacy environments.
- The current approach is scrutinised to see how to create 'natural' incentives or nudges for researchers and local facilitators to deliver the results of the trials back to participants.

We explored several elements in parts before compiling the actual prototypes.

Rankings

Rankings were used extensively in the original form. They are ideal for displaying data if there are relatively few data points. Extra graphic elements can be added to emphasise the results from the ranking exercises.

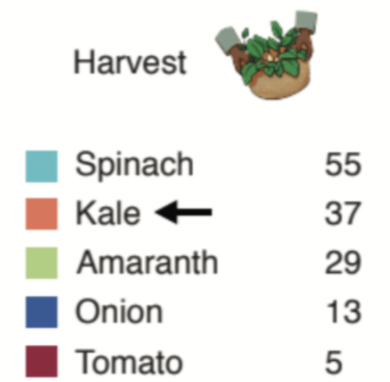


Figure 51: Visualisation of results using ranked data

Bar plots

These graphics associate data with the height or length of a bar. They offer a simple way to visualise both positive and negative space. See the example below: the bar plot shows how many farmers would grow the listed crops again, and the negative space shows how many would not grow these crops again.

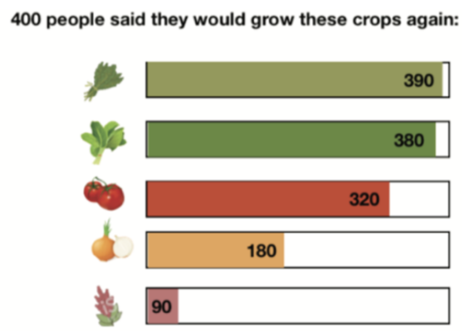


Figure 52: Visualisation of results using bar plots

Icons

The feedback sheet is intended for participants who may have low literacy levels. Form design might become easier to read and understand if the information is supported by visual aids such as symbols, icons, and data visualizations. Realistic icons, if well designed, are an effective way to support data interpretation. For example, instead of only writing the names of crops icons or other visual elements that can be added to increase understanding.

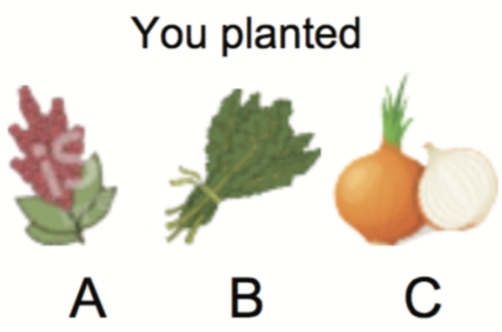


Figure 53: Visualisation of different crops used in a tricot trial experiment

Certificates

Offering some kind of social recognition after a trial might increase the engagement of the user group.

Figure 54: Example of a certificate

Crop specific growing information

The current feedback sheet consists of quantitative data. Participants have indicated an interest in receiving agronomic advice concerning the varieties included in the *tricot* trial. Creating individual crop cards as part of a feedback package or dedicating part of the feedback sheet to provide crop-specific planting advice or pest and diseases information, might enhance the value of the feedback.

Figure 55: Example of crop information template

Visual identity for different crops

We have tried to make the varieties easier to differentiate by making associations with colors, patterns, or symbols. Crop varieties often only marginal differ compared with other varieties, e.g. They have a similar appearance. Therefore using specific icons to differentiate between the different varieties does not work. 'Branding' each of the varieties included in the *tricot* trials might increase the readability of the results, rather than only by name. We used colors, patterns, or symbols to differentiate the varieties.

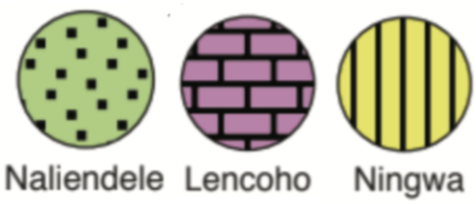


Figure 56: Combining patterns and colours

Prototypes

We designed two prototypes for feedback delivery of the results using paper templates. The first prototype consisted of a certificate of completion of the trial, an indication of which crops the individual participant received, and a bar chart indicating the overall ranked crop performance and for different traits.

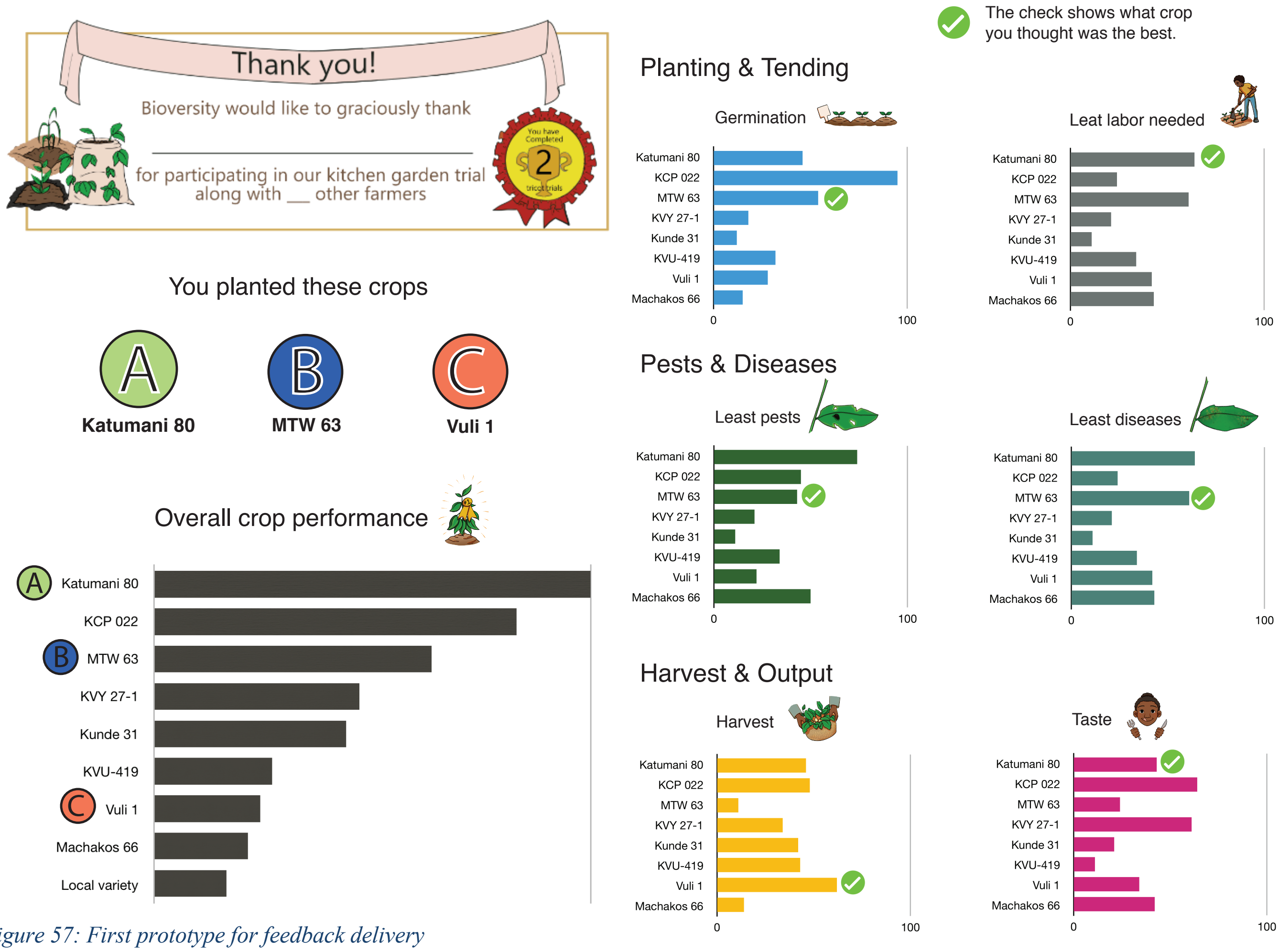
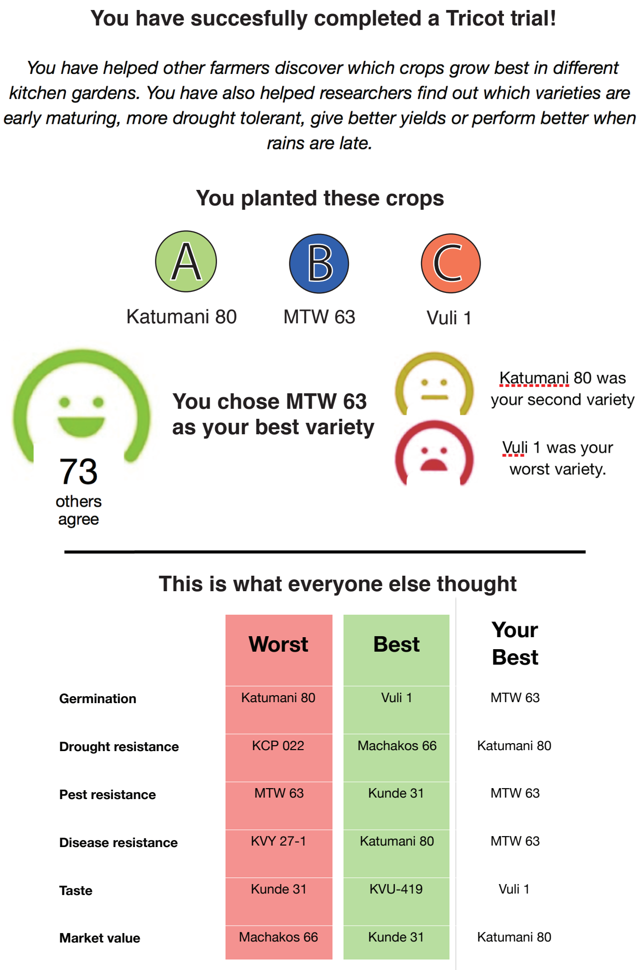


Figure 57: First prototype for feedback delivery

The second prototype included a description of the individual participants' contribution to research, showed which crops they planted in their trial and which crops they ranked highest. It contained a table comparing the least preferred and most preferred varieties for different crop traits and a brief description of each variety.



Variety	Description
Katumani 80	Moderately resistant to pests, grows well in dry areas
KCP 022	Drought tolerant
MTW 63	Pest tolerant
KVY 27-1	Moderately resistant to several pest and diseases
Kunde 31	Dual purpose (both leaves and seeds), grows in high altitude
KVU-419	Recovers fast from drought, tolerant to cold
Vuli 1	Disease resistance, good taste
Machakos 66	Disease resistance

Figure 58: Second prototype for feedback delivery

In the second round of field testing, we redesigned the feedback sheets based on the suggestions from participants in the first round.

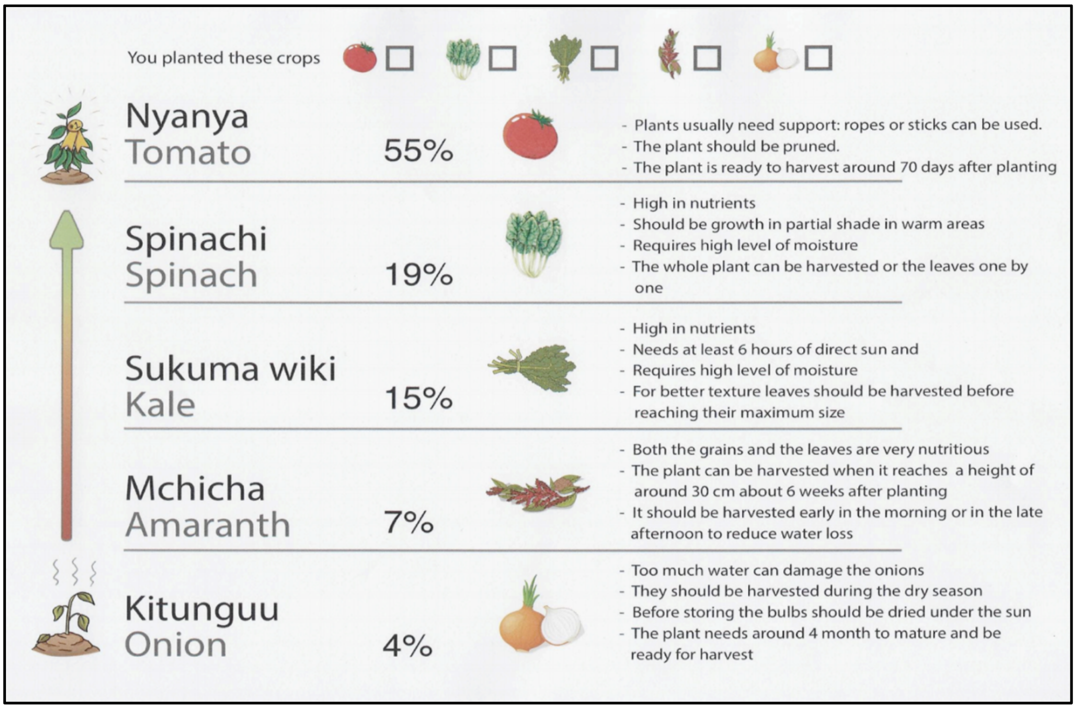


Figure 59: Third prototype for feedback delivery

We also included a less graphic version of the feedback sheet resembling the current state of feedback delivery in tricot. We based our hypothetical examples on actual data from ongoing tricot trials.

Thank you for participating!
Peter Mulwa
Tuma Farmer Organization
Mtito Andei

These are the results of the Tricot experiment

- These are the crops you had and how you ranked them:

Position 1	Position 2	Position 3
Spinach	**Onion**	**Tomato**
		

- These are your observations

Characteristic	Best	Second	Worst
Disease resistance	Spinach	Tomato	Onion
Pest resistance	Spinach	Onion	Tomato
Water use	Onion	Spinach	Tomato
Labor	Spinach	Onion	Tomato
Harvest	Tomato	Spinach	Onion
Money saved	Spinach	Onion	Tomato
Value in the market	Tomato	Onion	Spinach
Taste	Tomato	Spinach	Onion

- These are the best and the worst crops in the community:

Best

Position 1	Spinach
Position 2	Kale
Position 3	Tomato
Position 4	Onion
Position 5	Amaranth

Worst

1

Figure 60: Fourth prototype for feedback delivery

8.4.2 Field testing

During the first field tests, we learned that the hypothetical scenarios we put forward in our design sessions were difficult to understand for the participants (and perhaps also the local facilitators). In the first round (10 August 2018) we asked farmers to imagine that they completed a tricot trial. And that they would now receive feedback. This did not work well. This scenario setting confused the participants and they remarked that the results did not align with their own experience, or started filling the empty templates rather than commenting on the designs. In the second round of field testing, we set aside more time to set the scene and told the participants that they are looking at a hypothetical cowpea experiment and received feedback on the results from all 300 other participants. Still, this did not work well, mostly as farmers are familiar with cowpea varieties and started questioning the data we represented. We should have taken more time to create realistic representations. In the third round (16 August 2018) we asked farmers to imagine these were the results of other farmers seemed to work more effectively. Not having to imagine these were their own results was easier for the farmers and made it much simpler to explain and translate.

Learning

Participants did not realise that the forms contained different visualizations of the same data and therefore thought it was a strange task to compare them. It is difficult to value the need for feedback on the results for participants who do not have a full understanding of the tricot research in the first place. Furthermore, the fact that we tried to present them with 'made-up' results which do not match the experience and observations of participants, added to the confusion. This limited the learning opportunity.

They first looked at the tables. The information at the top is scanned and not recognised as important. They usually start from the bottom and work their way up. They were not sure what the percentages represent. There were no labels explaining what the percentages meant.

In the third round, we noticed that testing the individual forms in pairs was a good idea. The participants seemed to prefer having a chance to discuss this with someone else and it meant they could interpret the form together. This also made the testing go faster.

Having these groups come together to discuss provided good data. The groups, being able to discuss among many people (6 in this testing) meant that there was less likelihood of only one voice dominating the discussion. The fact that people have access to different forms, and therefore different knowledge prevented the likelihood that a dominant voice dominates the discussion. The discussion still often needs to be prompted. Participants are not likely to fully discuss the form and the actual way in which the information is presented, they need prompting to tease out the information they want.

Testing three forms at once worked well. Having more points for comparison meant we could see better what they did and didn't like and they can make more informed choices of what their favorite was.

Enjoyment

In the following rounds more and more people showed up to participate. They seemed interested to learn what these researchers were coming to research in their area. They were willing to contribute to the research, without receiving any form of compensation. The exercise was not particularly difficult for them and seemed enjoyable.

Instead of using a hypothetical example for testing the feedback card, we should use the actual experiment. We have to find a way to visualise that the results are from 300 other participants who conducted similar experiments and that there is value in that information by communicating our value proposition clearly. And emphasising that we are evaluating a range of different varieties or crops. Their 3 varieties are part of a larger evaluation of different varieties or crops and by submitting their evaluation they will also get to learn about varieties that others have tested for them.

We needed to rethink the labelling of the different varieties as the A, B and C labels caused some confusion. Can we make this distinction more clear by using visual aids?

Providing feedback to farmers should be part of a group activity where one person explains what the information on the form means. Workshops are useful for delivering feedback to tricot users. Can we think of ways to incentivise the implementation of these workshops for the implementers? Perhaps by providing lead farmers and local facilitators with tools and games they can use to communicate feedback on the results of the trials back to the group. If we design a complete package with facilitation guides in addition to the results of the trials, and materials to implement the activities, we make it a worthwhile and straightforward process of delivering feedback. We could also break up the feedback delivery into parts that are distributed during regular group meetings. This information needs to be designed for a low-literacy audience: even if the implementers are unable to invest the time needed to deliver the feedback, the farmers and local facilitators can go through the materials themselves.

Rather than providing the individual results of the trials on paper forms and redesigning the data to make it visually more attractive, we could save these data visualizations for use in group settings. It became clear that participants are more interested in local results and comparisons with farmers or groups they know than the overall and perhaps more abstract results of the trials. Participants were interested in the agronomic knowledge of the varieties and requested that the provision of information about the different varieties should be the main focus of the feedback form. They would prefer information on planting and harvest times, pests and diseases, maturity period, and specific variety characteristics. Normally there is information on the packets that they buy, but since participants in tricot often receive blind trials (e.g. They do not know which varieties they will be growing) they won't have access to this information. It is difficult to get access to agronomic knowledge on different varieties in detail. Perhaps it is possible to design a worksheet format and ask them to bring their own observation card to regular meetings so they can compare their results with the other farmers in their group and discuss their performance.

Last, they would like to receive a certificate of completion.

8.5 Knowledge sharing activities

The previous two activities focused on form design as a means of collecting data and sharing feedback. In traditional extension and participatory agricultural research approaches, much of the knowledge dissemination is based on face-to-face interaction, meetings, and oral language. By designing knowledge-sharing activities we allow farmer groups to interpret and analyze feedback on the results of the tricot trials data independently. In this activity, we designed six group activities to explore which offer learning opportunities for the groups and can be used by experimental groups together with local facilitators. We developed different types of group activities, adapting them from literature (Boef and Thijssen, 2007; Gray *et al*., 2010) or from prior experience in working with farmer groups.

8.5.1 Design choices

Our design was guided by the following how-might-we questions:

1. How might we give actionable feedback to farmers when we are not with them in person?
The feedback had to be relevant to the current tricot experiments and focus on sharing best practices and experiences. The activities were focused on knowledge generated within their community of tricot farmers, their preferences and issues in the experiments, and how they were able to prioritise questions for obtaining expert advice to make the feedback more actionable. Activities should be easy to explain and implement using basic facilitation skills. We also made sure that the activities did not require a lot of resources or time to prepare or implement.

2. How might we vary how feedback is given received?
By testing different types of group activities, sometimes varying the playground ('Bodystorming' versus 'Jar visualization') and sometimes varying the knowledge sharing process (telling stories in 'Campfire' versus question generation in '20 Questions') or in 'the Squid') and using different tools to ensure that all participants are engaged (the use of a ball to pass around versus a dice). We also wanted to test more 'scripted' activities ('20 Questions') versus more open formats ('Campfire').

3. How might we make participants discover the feedback of others (and other tricot trials)?
We based our activities on making use of the knowledge that participants have gained by participating in tricot. Facilitating knowledge sharing through various group activities allowed the participants to compare and rate their own success. They were also able to pose questions that the group could attempt to find the answers for themselves.

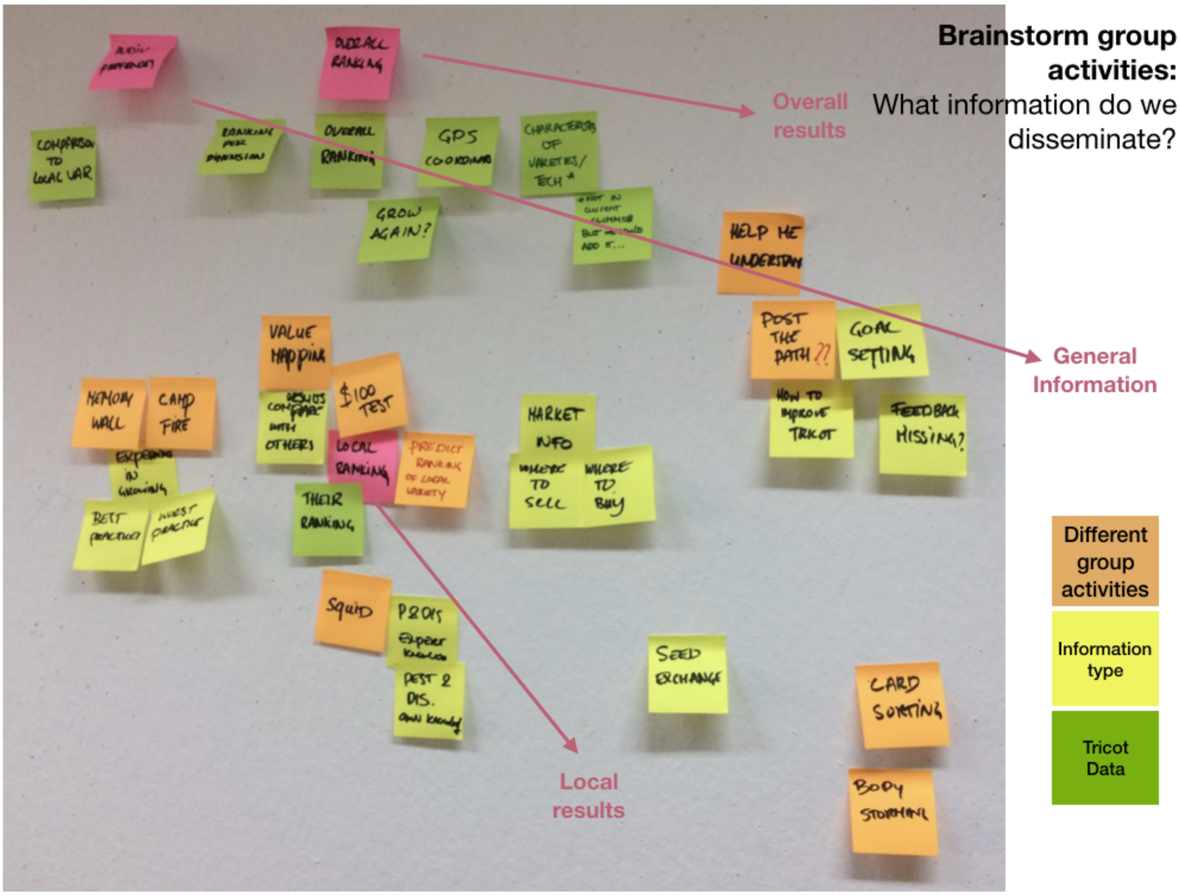


Figure 61: Brainstorming activities

For example, the 'Campfire' exercise and '20 Questions' make use of a deck of cards representing different variables in farming:

- Farm activities (farming, observing, planting, fencing, weeding, harvesting, watering).
- Farming practices (applying manure, preventing crop disease, water use).
- External effects (drought, rain, pests, elephants, pests, and diseases).
- Types of kitchen gardens (sack garden, wet bed, zaipit)
- Crops (kale, spinach, amaranth, onion, tomato).
- Miscellaneous (money, food, marketing).
- Blank cards

We used different game elements. For example the use of a small football that participants can throw around to give the turn to the next participant. Or throwing a dice to determine the next topic of discussion.

Dice templates were used.

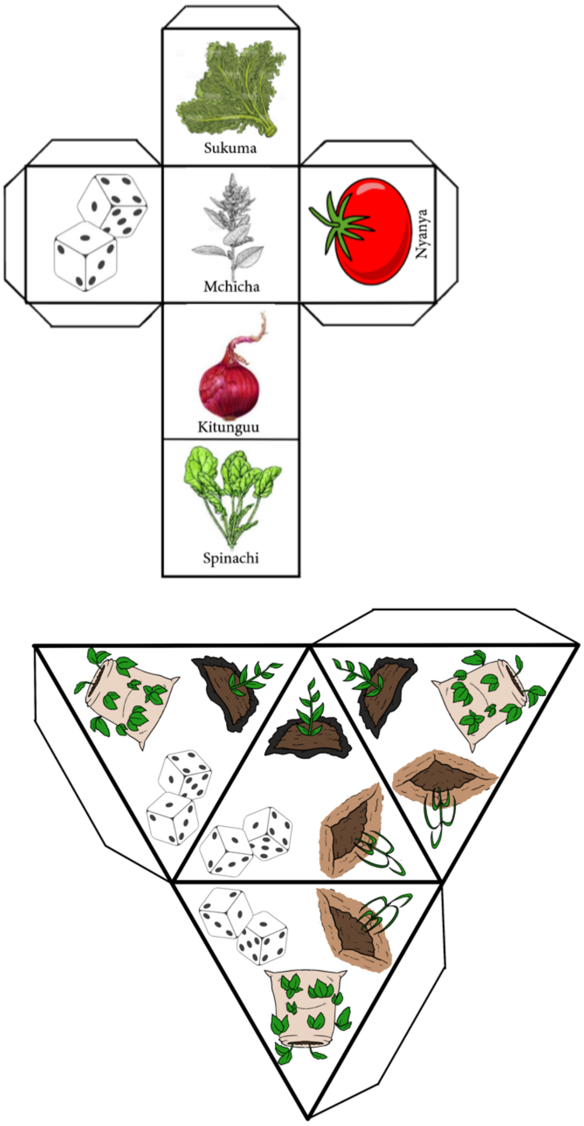


Figure 62: Customised dice templates

8.5.2 Activity descriptions

The Squid activity (Gray *et al*., 2010, p.208).

The group chooses a topic which they want to cover. They write the topic in the middle on the left side of a large piece of paper. They then generate questions based on the topic. After writing a few questions down, the group tries to answer the questions themselves. The answers are noted down next to the question. Questions that cannot be answered by the group are marked with star shapes to indicate that these questions require outside expertise.

This process is repeated several times until the group decides that no more questions remain to be asked. The group then discusses which questions should be sent on to receive expert advice and from which sources as well as which form they would prefer to receive the answers.

This exercise helps a group explore an information space, and how they can focus their attention on where they currently lack knowledge. By reaching a consensus over which questions to prioritise, and how to acquire expert advice the group creates a clear path forward. This strengthens the voice of the group in obtaining valuable advice rather than ‘waiting to see what the expert will bring’.

Campfire/Card Selection activity (Gray et al., 2010: 156)

We used role-play to introduce the goals of the exercise as the facilitator explains the different steps in the process.

A set of 20 cardboard cards representing various activities related to local farming practices and participatory agricultural research are placed on a flat surface in front of the group. A small football is passed around. When they receive the ball, they stand up and select one of the activity cards or a blank card. They then proceed to share what they perceive as ‘best practice’ in relation to the activity represented on the card. They are free to change this subject and tell any story as long as it is somehow related to the activity represented on the card. When they finish they return the card and pass on the football to someone else.

This activity reveals common interests and issues. As Gray *et al*. (2010) mention: “*Campfire leverages our natural storytelling tendencies by giving players a format and a space in which to share work stories—of trial and error, failure and success, competition, diplomacy, and teamwork*.” A common dynamic in participatory agricultural research is that researchers stand in front of a group of farmers, lecturing them or sharing knowledge that they assume is important for farmers to learn. There isn’t much of a discussion and when inputs are specifically asked. Detachment from or unfamiliarity with the purpose of the visit might have resulted in socially desirable inputs (Crowne and Marlowe, 1960; Vesely and Klöckner, 2020). An often-heard sentiment is: just tell us what we need to know/need to do. This activity can help reverse this tendency and create a more fertile knowledge-sharing space for the group including the researchers. It might help give people a voice who otherwise wouldn't feel they have much to share. Furthermore, much of the knowledge gained is through storytelling, rather than by reading a book or listening to expert advice. Peers train each other by sharing their personal experiences and considerations and this activity emulates this.

We need to set up the area as an arena or half circle to make sure that speakers can face everyone. A circle is not ideal for this exercise as people will naturally face researchers and never face some people. The board with the cards should be visible to all participants. It might be a good idea to go through the cards one by one before placing them on the board, so that everyone understands the concepts and what they can choose from.

Although this activity is good for sharing knowledge, it might also lead to sharing obvious statements and lack a bit of depth. We could use this as an initial activity to open up the discussion, followed by a prioritizing exercise (SQUID). We could create a worksheet where we visualise the story thread (see figure 63). Repeat the storytelling until the participants have created a snake-like "story thread" which acts as an archive of the activity.

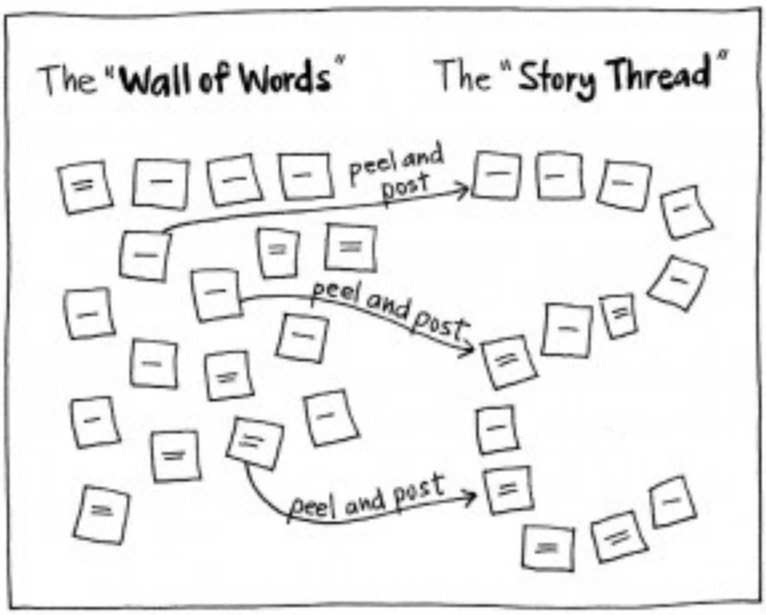


Figure 63: Activity cards (source: Gray et al., 2010, pg 157)

Another idea is to create a worksheet or booklet with all the knowledge shared. This can be distributed after the meeting has ended. Although this requires the implementing organization to collect the data, process it, and redistribute it and might lead to delayed responses.

20 Questions

We used a variant of the campfire activity where people select one of the cards and this prompts the facilitator to ask them a question tied to each of the cards.

Ideally, participants should be situated in a semicircle, so the one that comes to the center to talk can face all the participants. This ensures that all participants can see the cards. The questions should be noted down on a sheet of manila paper or flipchart to capture the storyline and document the process.

If we want to use the original exercise we have to invest more time in creating open-ended questions and a script for prompting. We should also rearrange the room in such a way they cannot stand with their back to the rest of the participants. And stimulate the audience to ask follow-up questions.

We should limit the number of people participating in this exercise. We had 16 participants and this seems too many. With the current rules-of-the game often the same people end up asking questions to the participants. Or it becomes a back and forward between two people.

The second version of the activity allows participants to ask questions which are interesting for them and build a discussion around them. However when this happens the discussion can last quite a long, so it is important to cut it out on time.

Also, it is quite likely that the questions will be asked by the same participants. To avoid this the ball could be passed around, so the one who gets the ball is the one who makes the question, and the one in the middle replies.

Dice Roll activity

We used a variant of the campfire activity where people roll a dice with *tricot* experiment types and/or roll another dice with crops used in the *tricot* approach. We asked participants to share a best practice related to the crop or the experiment type.

One way in which this activity could be improved for future implementations could be to include a dice with the different dimensions being observed by the participants. This would be both a visual prompt and a familiar one that would give a more specific area for the participant and the group to discuss. This could perhaps be combined with the later iteration of 20 questions, where the group can ask the participant about their knowledge on this topic with regards to their crop.

The crop itself, in a normal tricot implementation, could be represented on the four-sided die as A, B, C, and a rerolling option to ensure there would be no issue of having not grown the crop. The activity should also have a solid guide for implementers including guiding and encouraging questions to further discussion and prompts for the participant and group as a whole to try and get everyone more involved. The space itself should be carefully structured to ensure the person rolling the dice has to face the majority of the group and not resort to simply facing and addressing the implementer/researcher.

Jar Visualisation activity

Participants received 6 marbles each and were asked to allocate them to the different jars representing each crop for their best-performing crops. They could allocate the marbles freely by putting all 6 marbles in one jar or distribute them over multiple jars.. The result can be repeated by the researcher for showing the overall results of the trials. The activity offers a quick approach to getting an overall ranking from farmers without being influenced by others in the group and offers a direct visualization of the results. This opens up space for discussion.

Body storming activity

We used a variant of the jar visualization activity where people are asked to stand in specifically demarcated areas depending on which crop they considered to be the best performing. This provides an opportunity to get a quick representation of the results without making them too formal.

This activity needs proper facilitation and a clear activity leader. Besides explaining the activity beforehand through role-play, we should also talk participants through it as they are rearranging themselves / as they are pursuing the activity. We need a facilitator that uses their voice to talk the participants through all the steps. Can we use prompts (visual aids) to start the discussion? There should be a designated area for this activity. It should not be uncomfortable for the participants to stand there. This activity should be kept short. It is more an energiser or a start of another activity.

8.5.3 Insights gained during implementation

To generate insights gained during field implementation of the activities, we scored each of the six knowledge sharing activities on different dimensions.

1. *Facilitation level*: basic skills level required from the facilitator
2. *Time:* estimated duration of the activity
3. *Learning:* the ability to learn from the activity (learning potential)
4. *Enjoyment:* ranking of the activities that we felt participants enjoyed most
5. *Engagement*: how engaged we felt that participants were (based on observations)
6. *Ease-of-use:* how easy is it to implement the activity in field conditions
7. *Understanding*: how easy it was to understand the activity (based on our observations)
8. *Usefulness*: the overall usefulness of the activity in delivering feedback

Activities	**1. Facilitation level**	**2. Time**	**3. Learning**	**4. Enjoyment**	**5. Engagement**	**6. Ease of use**	**7. Understanding**	**8. Usefulness**
Squid	Medium to High	45 min	(very) good	5	Good	Easy	Yes	Very useful
Campfire	Low	40-60 min	Good	6	Very good	Very easy	Yes	Very useful
Bodystorming	Low	15-30 min	Poor	1	Poor	Difficult	No	Not useful in this form
Dice roll	Low to Medium	20-40 min	Ok	2	Ok	Somewhat difficult	Somehow	Moderately useful
20 Questions	Med-High	30 min	No	-	Poor	Easy	Somehow	Not useful in this form

Jar visualization	Medium	15-30 min	Ok	3	Ok	Not so difficult	Somehow	Moderately useful

The individual scores are summarised in the table above.

1. In terms of the *facilitation level*, we selected activities taking into account low to medium facilitation levels. Whilst some of the activities require more facilitation than others (f.e. 'The Squid' and '20 Questions') none of the activities require high facilitation skills.
2. The estimated *duration* of the activity depends on the number of participants and the number of turns per participant. Taking time before each activity to do a role-play enhances participants' understanding and subsequently the experience in itself. It also saves time explaining activities multiple times throughout the activity. Activities naturally came to an end in about 45 minutes, even if we had planned more time for the activity.
3. Three of the activities were evaluated "poor" ('20 Questions' in its original form) or "ok" in terms of their *learning potential*. These activities need to be redesigned if we want to use them as a feedback delivery activity. For example, we should have a scripted format to structure the activity and think about the sequence of activities so that one activity naturally flows into the next activity where there is more emphasis on knowledge sharing.
4. We ranked the six activities for *enjoyment* (based on our observations) and found that knowledge sharing activities ('The Squid' and 'Campfire') were found to be most enjoyable. These activities provide the participant with a certain level of autonomy as they get to choose their topics for discussion. The visual aids (activity cards, process-visualizations) and the ball for passing turns to other participants increased the enjoyment.
5. Similar to enjoyment, engagement was highest in 'The Squid' and 'Campfire' and the adapted format of '20 Questions'. The engagement was lower in the activities that followed a more structured approach where participants did not get to choose their topics. For example in the activity 'Dice Roll' you share experiences based on the icons on the dice. Not everyone had an experience at hand that they wished to share for the given combination of kitchen garden and crop. This led some participants to make obvious statements instead of sharing best practices or

experiences. This lack of depth in the discussions led to disengagement. The dice roll would be a good alternative if the workshop takes place in a small group where people would be sitting around a table.

6. Having the right visual aids for most of the activities made them fairly *easy to implement*. They all required some preparatory work beforehand in creating activity cards, designing and assembling dices, and printing out labels and questions. When adopted in the tricot feedback workshops this preparatory work could be limited to filling, printing, and assembling templates.
7. The 'Bodystorming' activity and the 'Dice roll' required a bit more explanation before it was understood. The activities that required a 'talk-through' during the process were more difficult to understand.
8. Some of the activities need to be redesigned to increase their usefulness ('Bodystorming' and '20 Questions') and some of the activities are better as part of other activities. For example, jar visualization could be used in a knowledge-sharing activity to provide it with more context.

8.6 Graphic literacy

One of the major learning outcomes from the *tricot* approach is quantitative data on crop variety preferences by combining farmer-collected data from a large number of participants. To achieve this learning outcome, data needs to be presented to the participants in a format suitable for all participants. Visual displays of the data are used to communicate the results and require varying levels of graphic literacy. Graphic literacy is the ability to understand graphically presented information, for example, tables or bar charts or other graphic representations of data (Galesic and Garcia-Retamero, 2011). Learning outcomes need to match the ability of the participants to offer functional benefits. We measured the graphic literacy levels of participants to gain insights into their abilities to understand graphic representations of mock-up data, inspired by the work of Galesic and Garcia-Retamero (2011).

8.6.1 Activity description

We asked participants to interpret a set of eight visual representations of locally relevant data. The graphic representations were presented to them without any guidance and they were asked to interpret the data individually before asking for an explanation to confirm their assumptions. Researchers paired up with the participants and prompted them with specific questions for each graphic visualization (3-4 questions for each graph). If they were not able to answer the question or repeatedly asked for help, the researcher marked the question as ‘unanswered’.

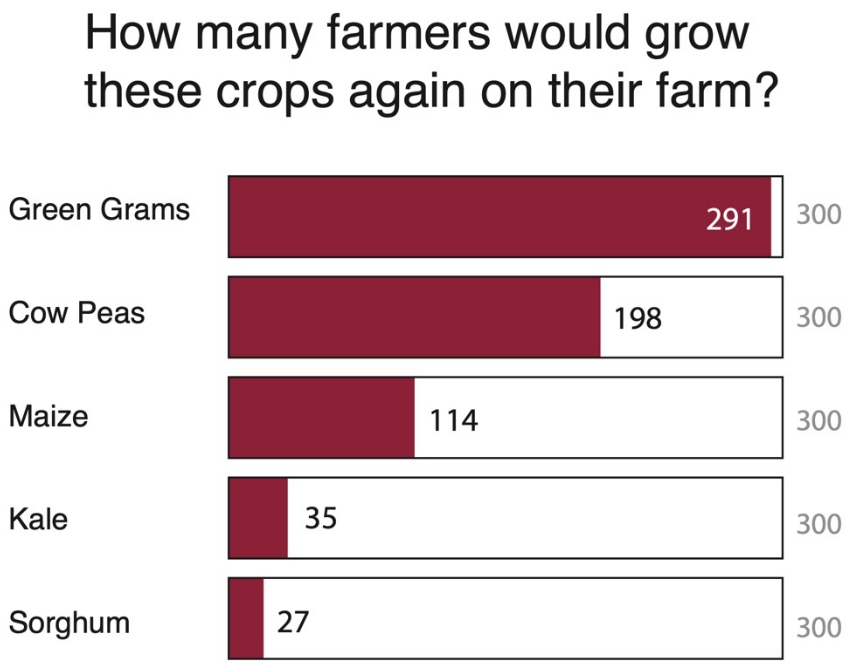


Figure 64: Bar chart for graphic literacy testing

Graph 1

- Which is the crop most people wanted to try again?
- Which is the crop fewest people wanted to try again?
- How many farmers wanted to grow Maize?
- Which crop did exactly 35 farmers want to grow again?

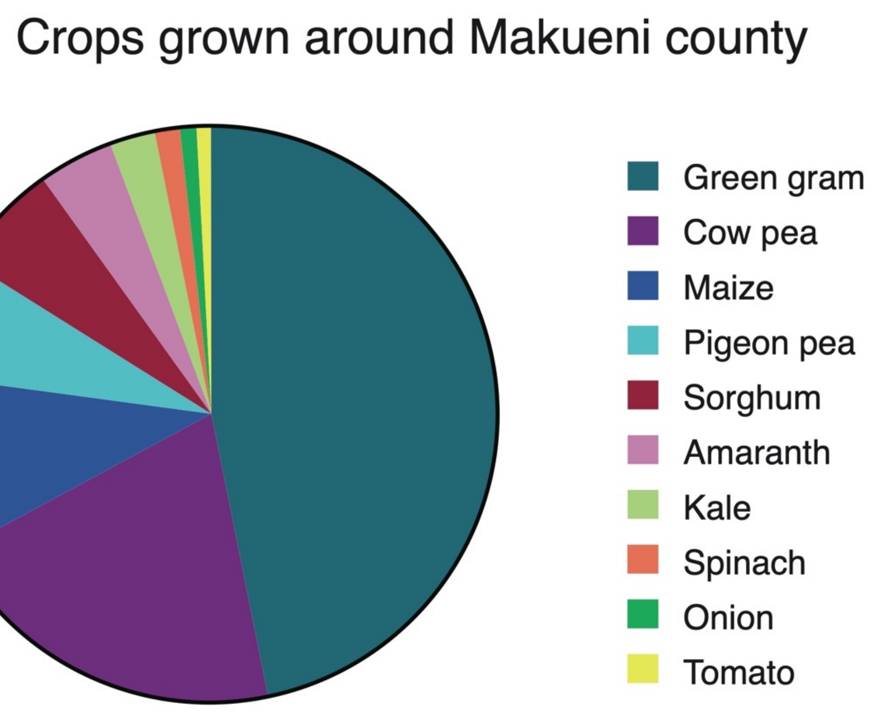


Figure 65: Pie chart for graphic literacy testing

Graph 2

- Which crop is grown the most?
- Which crop is grown the least?
- Can you show me where sorghum is in the circle/graph?
- [Point to cowpea/purple] which crop does this section/part of the circle represent?

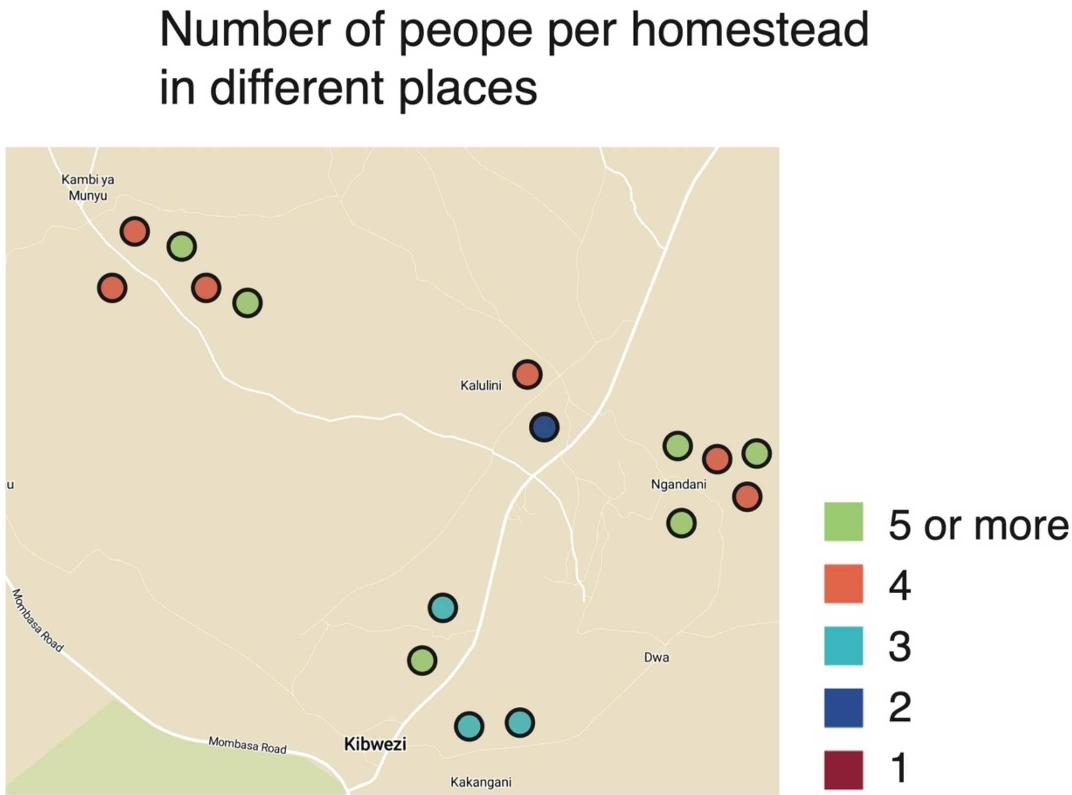


Figure 66: Spatial map for graphic literacy testing

Graph 3

- [Point to one low population dot] How many people live here?
- [Point to one high population dot] How many people live here?
- [Circle two different areas] Which area has the most amount of people?

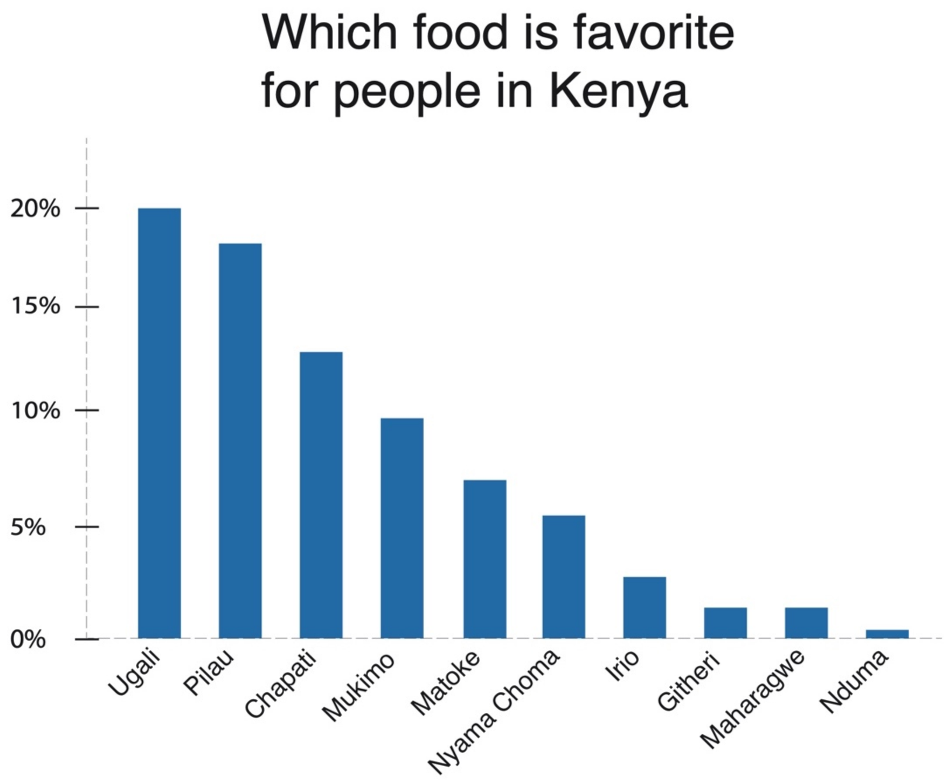


Figure 67: Column chart for graphic literacy testing

Graph 4

- What is people's favorite food?
- What is people's least favorite food?
- What percentage of people had Nyama Choma as their favorite food?
- What food did 9% of people say was their favorite?

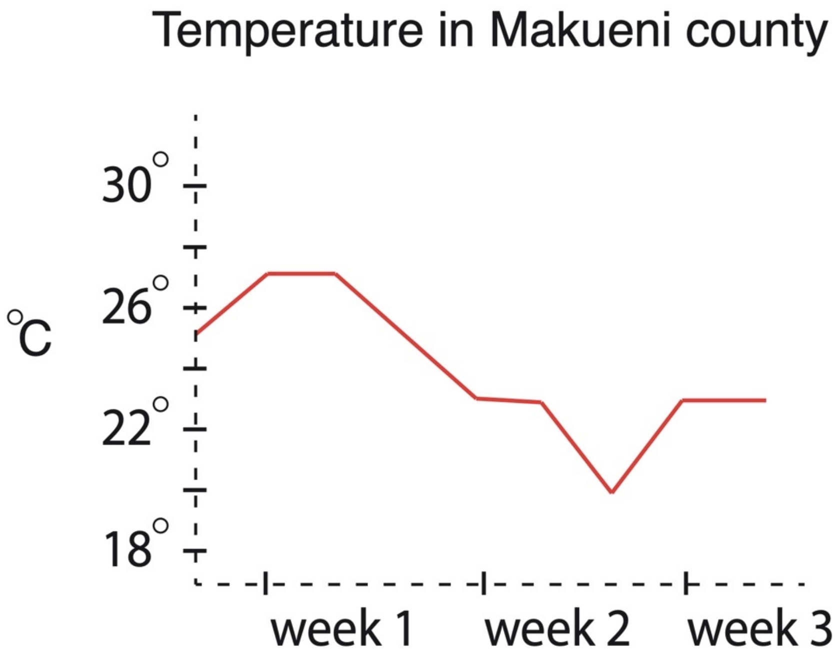


Figure 68: Line chart for graphic literacy testing

Graph 5

- Which week had the highest temperature?
- Which week had the lowest temperature?
- What was the temperature in week 3?

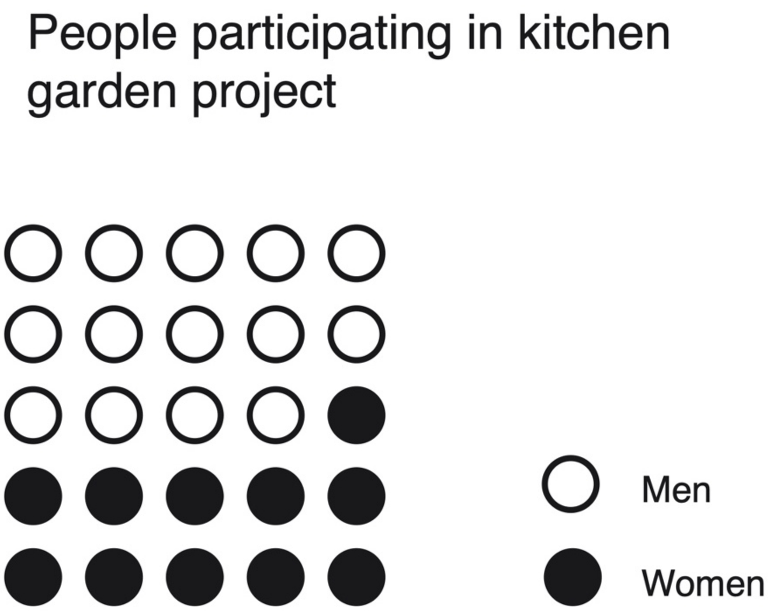


Figure 69: Pictogram use for graphic literacy testing

Graph 6

- What do the black dots represent?
- What do the white dots represent?
- Did more men or women take part in the kitchen garden project, according to this picture

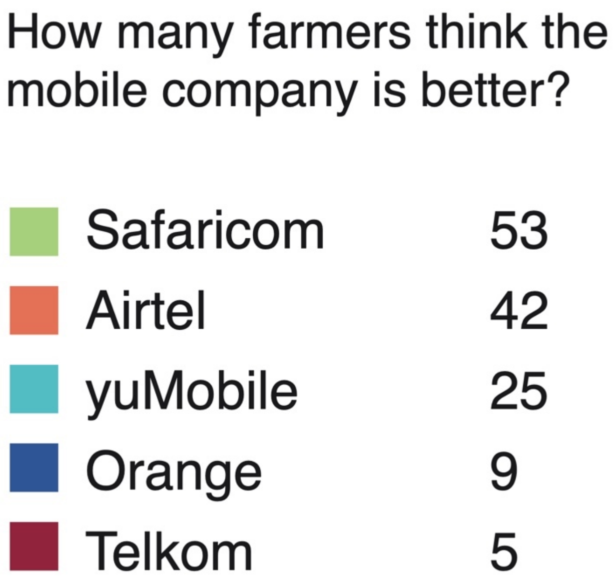


Figure 70: Data with numbers for graphic literacy testing

Graph 7

- Which company do most farmers prefer?
- Which company do least farmers prefer?
- How many people prefer Orange?
- Which mobile company is preferred by 25 people?

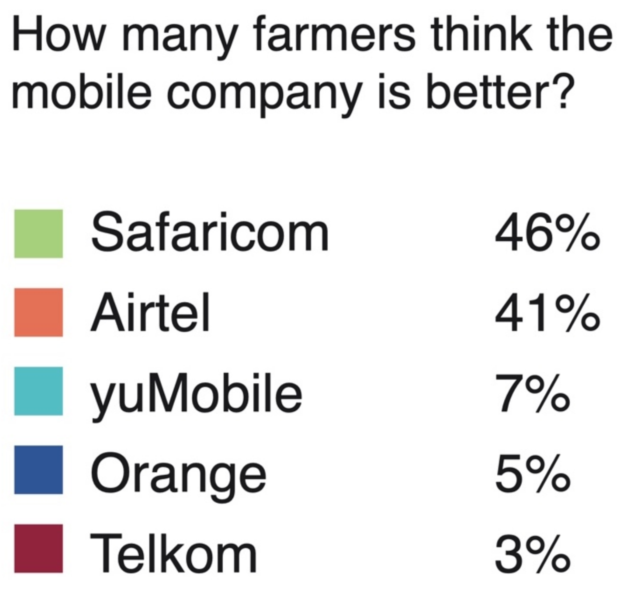


Figure 71: Data representing percentages for graphic literacy testing

Graph 8

- Which company do most farmers prefer?
- Which company do least farmers prefer?
- How many people prefer yumobile?
- Which mobile company is preferred by 41% of people?

8.6.2 Findings

We collected data points for a total of 16 respondents who answered all the questions linked to the eight graphic representations.

Graph 1 (Bar chart)

- A few people asked for help with translating the graphic. For example, why do we have these lines with colors? Or why are some full and others not so full. However, a majority of the respondents were able to read the graphic and answer the questions.
- One or two of the respondents kept referring to their own experiences: "Nice to have

this info about others but from my experience, this is not accurate. So I would choose… "

Graph 2 (Pie chart)

- The colors of the pie chart were not properly visible in the printed version of the test. Both cowpea and sorghum came across as purple.
- The question on which crop is grown the least caused some confusion and answered mostly varied between tomato or onion.
- Respondents indicated their own preference for crops rather than interpreting the graph.
- One respondent asked why the legend was not inserted in the pie chart but placed outside.

Graph 3 (Spatial map)

- Only 54% of the respondents were able to answer the questions correctly. Compared to the other graphics, the spatial map offered the biggest difficulty in reading.

Graph 4 (Column chart)

- Respondents brought in personal experience rather than interpreting the data.
- Finding a percentage based on a prompt seemed easy (What percentage of people had Nyama Choma as their favorite food?) And only 1 respondent failed to answer the question. However, 7 respondents failed to answer the last question which lets respondents read the vertical axis (what food did 9% of people say was their favorite?).

Graph 5 (Line graph)

- Respondents interpreted the questions on the highest and lowest temperatures differently than intended and read the vertical axis minimum and maximum values (18 - 30 degrees) rather than interpreting the line.
- The fact that each week in itself contained multiple points led to confusion with at least one of the respondents.

Graph 6 (Pictograms)

- This graphic was easy to understand, only one respondent failed to understand the questions.

Graph 7 (table with numbers) and Graph 8 (table with percentages)

- Respondents bring in personal preferences in terms of the mobile company they think is most popular, rather than interpreting the data. One farmer said she only knew Safaricom so couldn't answer the questions.
- Only one respondent had difficulties answering the questions and interpreting the data.
- There seems to be a slight preference for the use of percentages over numbers as it is more clear what it represents.

Four factors are said to influence the level of understanding of graphic visualizations: previous knowledge of graphics, previous knowledge about the content of the graphic (which will help interpret the data), the visual representation (color use, data density), and the type of graphic and how they are used. For example, line graphics are better for reading trends, bar charts for individual data points, and pie charts to visualise how one part measures up to the whole.

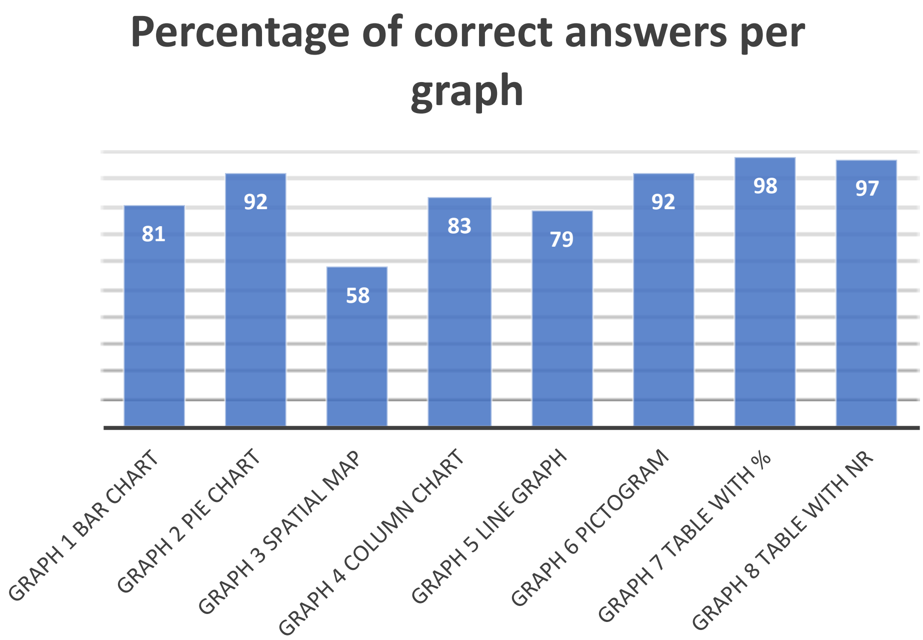


Figure 72: Correct answers provided for each of the graphics

The only outlier here is the spatial map representation and this might be caused by how the questions were phrased. Overall all graphics are well understood by most of the respondents. Scores varied between 66% and 100% correct answers per questionnaire with a median of 91%. Therefore, we can assume that our target audience is graphically literate.

8.6.3 Reflections on the process

This activity should be viewed as an exploratory assessment to generate insights into the activity of graphic literacy testing. In future assessments, it would be good to pre-test the graphic representations before use to ensure appropriateness. The questions should be asked about information that is familiar to the respondents, but not information for which the answers are self-evident. For example, the question in graph 7 asks which mobile company is the most popular. Safaricom holds 70% of all phone plans in Kenya. Therefore respondents can answer this question right whether they can read the graph or not.

8.6.4 Moving forward

A robust assessment of graphic literacy would require a more in-depth study into the ability of participants to understand and interpret the visual representations. Several researchers use three levels of graphic comprehension; an elementary level where the respondent can read a specific value in a graphic; the intermediate level where the respondent can identify relationships or trends; and an advanced level where the respondent can 'read between the lines or read beyond what is visually represented and distill meaning (Glazer, 2011; Lai *et al.*, 2016; Lee *et al.*, 2016; Lee, Kim and Kwon, 2017). This graphic literacy assessment focused on the elementary level only (can they interpret the visual representations correctly?). It would be interesting to include elements that allow us to assess deeper levels of understanding by rephrasing questions and using graphic representations of multidimensional data.

8.7 Discussion

Participants in the prototyping experiment were willing to contribute to the design process and provided insights that would have been difficult to uncover otherwise. For example, insights generated on graphic literacy of the target audience are difficult to test in a (focus) group setting and should be done individually. Furthermore, the ability to observe participants filling the forms provided the researchers with plenty of insights on where people might get 'stuck' or where a form needs to insert clarifications. We started the chapter with two conceptual questions:

Question 1 (subjective level):
Can we make the processes of data collection and results sharing in tricot research more engaging for participants?

The field evaluation of the prototypes showed us that the early prototypes we designed did not match users' behavior. Users in the context of our research did not understand the use of the graphical representations of the data intended to provide feedback on the results of the trials. The context in which these results were provided seemed to be misunderstood or undervalued. The information provided in the data collection and feedback formats was insufficient and did not match with their needs for two reasons. First, users are not very interested in receiving abstract ranking information about a range of different varieties but would prefer to receive data that was further digested into market information or growing advice. It seems that they are more enticed by information that matches their oral culture than being presented with numbers and graphics. Even though graphic literacy was high for the participants in our study, this doesn't necessarily mean that their scientific literacy is equally high. Numbers might hold as much meaning for our target audience as it would for researchers or people who regularly digest scientific information. Secondly, we initially limited ourselves to prototypes on A4 printed forms and we should have been more open to thinking creatively on how and where the forms would be used. For example, the data collection formats should be used in farmers' fields and regularly carried around the farms whilst users make their observations. A4 printed formats are quite useless in this context. Rethinking the type or size of paper we use or how the use of tick boxes influences the ability of participants to provide accurate answers were some of the insights we gained during fieldwork. A relatively standard set of activities already showed us its applicability in our user context. With more time, we would have easily been able to develop a set of feedback lessons that local facilitators and lead farmers could use as scaffolding for designing their own. However, we also discovered that without sufficient accountability of the researchers and the local implementers, any type of design for delivering feedback is likely to miss its target. Simplifying the process of feedback delivery is not going to solve this issue.

A brief literature review on graph(ic) literacy and visualization literacy indicates that there is currently a lack of empirical evidence outside of western society. The experiences we gained with graphic literacy assessments show the applicability of the frameworks presented by both Lee *et al*. (2016) and Galesic and Garcia-Retamero (2011).
Graphic literacy assessments are feasible and useful to use in contexts outside the western world and provide useful information on how best to visualise data intended as feedback or bringing scientific information to rural populations outside the western world.

Question 2 (meta-level):
How might we use designerly approaches to involve rural farmers in the design process?

We were able to solicit feedback on the design of data collection and feedback delivery formats through field testing prototypes. This behavioral data showed us *how* people interact with the different formats rather than asking for approval or validation and relying on what people say they will do. Even though the feedback was not uniform and some people preferred prototype "a" over prototype "b" or tables over graphics, it was relatively straightforward to identify the low-lying fruits and incorporate these into our designs. Whilst going through a design cycle rather than just 'drafting a form' will still leave open endings and choices to make, however, we are now no longer 'fumbling in the dark' and can make a far more educated guess about what will work, based on inputs from end-users, rather than relying on our own experiences and assumptions. At the very least the designers will have created a document of what works and why certain decisions were made which will lead to more intentional design decisions when further iterating on these designs.

Rather than asking users for validation of already designed formats, or simply asking users what they need, it is better to include participants early on in the process and develop activities that will show what users will do with the prototypes. This requires solid facilitation skills of the implementing team. We are not asking users to evaluate forms or activities or to participate in a research process. We are asking users to provide inputs on the designs by pointing out their preferences, and showing the designers/researchers how participants will interact with and experience the prototypes we put in front of them. This purpose should be made clear before the activities start. Not everyone can afford to spend time helping designers build better forms or streamline a research process, especially when this might not bring direct benefits to them. Going through a whole cycle of participation before the actual participatory research has even started, may seem tedious but could save researchers considerable time in the long run as it contributes to a more appropriate design of the formats used to collect data and provide feedback. This provides a more efficient way of iteratively designing data collection and feedback formats, as opposed to improving these formats at the end of each research cycle based on what the users tell you.

8.8 Reflections

The design of prototypes with a multidisciplinary team of designers, researchers, and field officers greatly enhanced the experience of building the actual prototypes. For future work it would be even better if we designed prototypes using a form of participatory or cooperative prototyping (Bødker and Grønbæk, 1990) where a team of researchers (scientists), designers, field implementers, and users (farmers) come together to develop prototypes or imagine how we could collect useful data (without those dreaded forms) more intuitively. This seems like a great opportunity to apply participatory design principles to the field of agricultural technology design.

8.9 Conclusions

Through rapid prototyping, we were able to gain rich information on user preferences in how to receive feedback, what kind of information participants value most and how farmers read and understand forms. This behavioral data was collected in a relatively simple intervention involving just a small number of users. Spending this time at the front end of the design process might prevent many of the pitfalls of designing for users. Traditional forms of participatory agricultural research often follow a more or less standard scientific approach, which does not emphasise or explore the problem space from a designerly way of knowing. With this chapter, I show that research processes can be improved when more time is spent defining the problem space and developing the modes and accompanying tools or methods for communication.

Chapter 9

Research literacy and motivation

9.1 Introduction

An important question was left unanswered in the first design experiment; by designing more engaging forms for data collection and feedback delivery, we discovered that expectations driving motivations are not fully aligned with what the researchers had in mind. Placing research in the hands of farmers did not lead to increased motivation to stay engaged in the process and take up more responsibilities. Farmers were interested in participating in the trials and observing the crops on their own farms but often lacked the motivation to record the data at prescribed times or showed limited interest in the overall results from the crowdsourced data. This might have consequences on seeing the potential benefits beyond the findings from their own plots. Therefore, simply lowering the barriers to participation in tricot, which was the aim of the first design activity, will likely not lead to increased engagement on the side of the users. What is needed is a more intentional design of the research process to create meaningful experiences for participants to learn beyond comparing three varieties on their own farm and making the process of sharing their knowledge more worthwhile. In citizen science, participants are persuaded to complete a task, not by financial gain, but by the prospect of learning or sharing knowledge. Setting learning goals and outcomes can enhance the motivational benefits for participants.

However, a major hurdle that appears as a blind spot in the current citizen science discourse: existing literacy in the population, both scientific and numerical, is a precondition not necessarily for motivation or participation per se, but for any 'full' participation that goes beyond an extractive research-citizen relationship. Full participation means participants have a willingness to participate (motivation) and think they are capable of completing the tasks that the activity asks them to fulfill (self-efficacy).

I set up a second design experiment measuring levels of motivation and self-efficacy before and after a training intervention (see figure 73). In addition, I created a self-devised measure to observe any gains in understanding of the tricot research process. For this research, I refer to this as *research literacy*. I measure participants' level of understanding of the tricot research process and basic research skills such as the ability to evaluate and interpret knowledge, to interpret numerical data, to understand scientific concepts, and explain and predict outcomes based on their actions. In this design experiment, I aim to investigate if a correlation exists between research literacy and self-reported levels of motivation and self-efficacy and research literacy.

Three cycles of formative, generative and evaluative research with voluntary participants were carried out between August and October 2019 in rural farming communities in eastern Kenya. The research took place as part of a small-scale implementation of a citizen science-inspired research process under ecologically valid conditions.

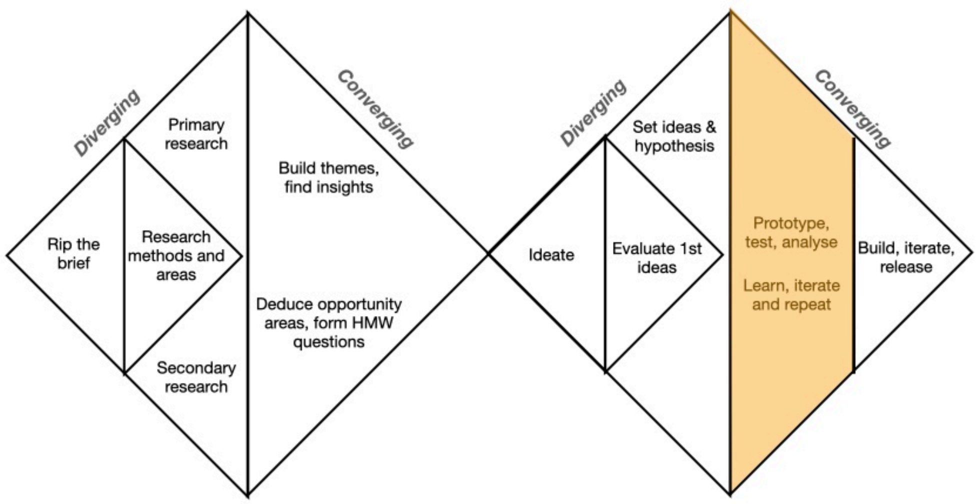


Figure 73: Stage 4 of the design process

9.2 Research Design

9.2.1 Research questions

We assume that participants initially sign up to participate in tricot trials because of extrinsic reasons, however, through instructional activities aimed at increasing the understanding of tricot, (parts of) this extrinsic motivation would be replaced by intrinsic forms of motivation. Application of the self-determination theory has consistently shown that more intrinsic motivation leads to a higher likelihood that certain behavior persists in the absence of extrinsic rewards or nudges and that people are more fully engaged in an activity or even perceive the activity as being more positive (Ryan and Deci, 2000). Therefore I want to find out if a better understanding of the tricot research process leads to higher intrinsic motivation amongst participants.

Research question 1

Is there a correlation between research literacy and levels of motivation or self-efficacy?

To test this hypothesis I aim to create a quantitative measure of motivation of potential tricot participants. I explore the link between research literacy and motivation and between research literacy and participants' perceived levels of self-efficacy using a measure-manipulate-measure design experiment.

Research question 2

Does the iterative design of a training activity show an increase in trainees' motivation, self-efficacy, and research literacy?

I used an iterative design approach to design training activities to increase participants' understanding of the tricot research process, explain basic research skills and interpret data and investigate feedback mechanisms. This second exploration is aimed at investigating whether this improved design leads to increased research literacy for the participants of the training session and if this has any impact on motivation and self-efficacy.

9.2.2 Experimental design

A pre-test was conducted with all participants before the intervention took place. The intervention was followed by a posttest. Participants were randomly assigned to a control group and a treatment group after conducting the pretest and their respective group code was noted down on the forms before handing these back to the researchers. In the first round of fieldwork, the pretest was administered before the treatment and a delayed posttest was administered with the same participants two weeks later. In rounds two and three the post-test followed immediately after the intervention, on the same day. This method was chosen to limit the external influences on the post-test. See figure 74 and 75.

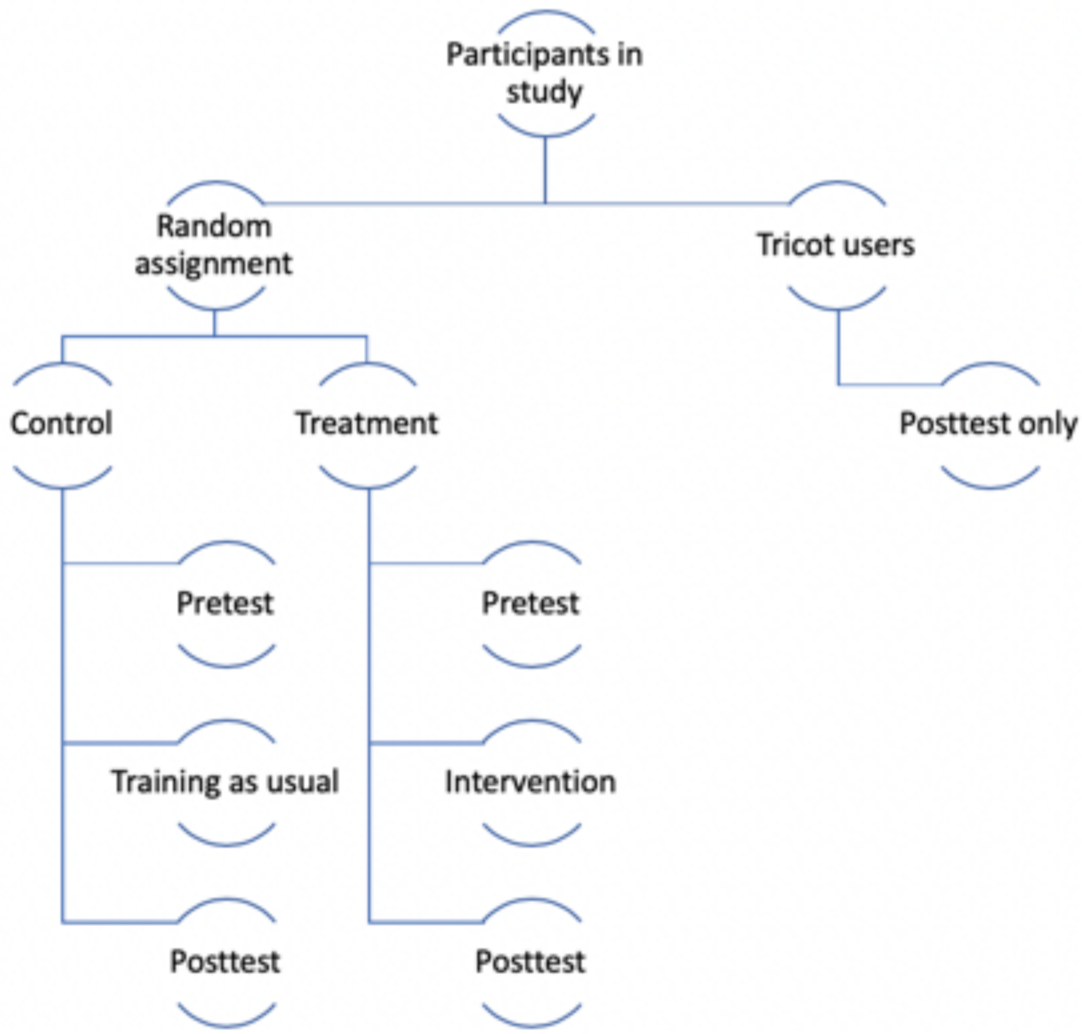


Figure 74: Experimental design

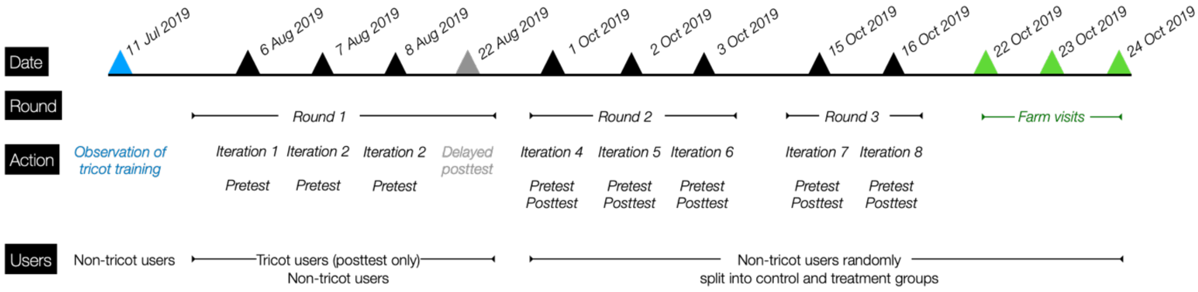


Figure 75: Timeline of design process

Selection of participants

Participants in the training activities were selected by Lutheran World Relief NGO who has an extensive network of farmer groups in Makueni and Machakos counties in Eastern Kenya. The NGO invited participants from existing farmer groups to participate, based on gender, their willingness to participate, and their exclusion from previous rounds of *tricot* trials. The number of participants ranged from 5-16 participants per location (mean=8). The total number of participants in this study was 159.

9.2.3 Quantitative data collection

Quantitative data was collected using a pre/post-test questionnaire measuring motivation, self-efficacy, and research literacy. I used self-reported measures to measure situational motivation derived from Guay *et al*. (Guay *et al*., 2000) and situational evaluation scales for measuring self-efficacy in citizen science projects (Phillips *et al*., 2018). See table 5 for an overview of the different measurements contained in the two scales. In addition, I created a self-devised scale to assess the levels of understanding of the (tricot) research processes.

Table 5: Overview of motivational scales

Code	**Description**	**Survey Questions**	**Measure**
SIMS_INT	Intrinsic Motivation	1, 5, 9, 13	7-point scale
SIMS_IR	Internal Regulation	2, 6, 10, 14	7-point scale

SIMS_ER	External Regulation	3, 7, 11, 15	7-point scale
SIMS_AMOT	Amotivation	4, 8, 12, 16	7-point scale
SELDS	Self Efficacy For Learning and Doing Science	17-20	5-point scale
SED	Self Efficacy for Learning and Doing Tricot	21-24	5-point scale
INTEREST	Interest in Science and Nature	25-30	5-point scale
SKILLS	Skills for Science Inquiry	31-39	5-point scale
LITERACY	Research Literacy for Tricot	40-43	Open-ended

General data

The pre/post-test questionnaire captured the following general data: gender, year of birth, the highest level of education completed (none, primary, secondary, above), research experience (1 = no, never, 2 = yes, once, 3 = yes, more than once) and their role in farmer group (member, treasury, chairman, etc.).

Measuring situational motivation

I adapted the situated evaluation scales used to evaluate citizen science projects for their outcomes, developed by Cornell's Lab of Ornithology. The questionnaires about interest, self-efficacy, and skills provide a useful evaluation of people's perceived ability to participate in citizen-science research and do not have an extensively validated alternative. Several well-known examples exist for measuring the quality and quantity of human motivation for task completion.

Figure 76: Validating the pre-test questionnaire in the field (11 July 2019)

I am interested in measuring the *quantity* of motivation, rather than looking for the sources of motivation in participants. Measuring the quality of motivation without measuring the quantity, would be as if we are providing a recipe where we list all the ingredients without their measures. It will be difficult to create the recipe as intended if we do not know in which quantities to use the different ingredients. Four types of motivation underlie human behavior (Ryan and Deci, 2000). *Intrinsic motivation* is derived from the pleasure and satisfaction received of performing an activity for its own sake ("I do this activity because I enjoy doing it"). *External regulation* refers to behavior motivated by rewards or to avoid negative consequences ("I do this activity because I do not want to face the consequences if I don't"). *Identified regulation* refers to activities that are chosen by oneself, however not for the activity for its own sake, but rather as a means to an end ("I do this activity because it will bring me positive results"). Last, the authors characterise *Amotivation*, a type of motivation where individuals do not experience intrinsic or extrinsic motivation at all, and where individuals experience feelings of incompetency or uncontrollability ("I do this activity but I am not sure why or do not expect much from it"). The quantity of the four types of motivation is how the pie is divided into pieces (Deterding, pers. Comm 2019). If for any given activity the situational motivation in terms of one of the motivational types goes down, others will have to increase. Here, I intend to measure changes in motivation after an intervention aimed to improve participants' understanding of the research process. Therefore, it is vital to understand to what extent the pie is divided for each respondent. I look at validated instruments in the field of behavioral psychology which aim to measure different aspects of motivation, considering the use of the Behavioural Regulation in Exercise Questionnaire (BREQ-2) in Markland and Tobin (2004), Intrinsic Motivation Inventory (IMI) as reported by Willoughby (2015) and Intrinsic vs Extrinsic Orientation in Harter (1981). Harter (1981) uses the concept of effectance motivation which refers to "the desire for effective interaction with the environment" (White, 1969, p. 317). However, the measure aims to determine the components of intrinsic motivation, rather than the quantity of it. Willoughby (2015) assesses the quantity and quality of motivation of students to participate in physical education. He distinguishes between task goals made up of 'intrinsic' competence based on previous experience or perceived maximum potential, and competence in comparison with others (ego goals). Markland and Tobin (2016) developed the Behavioural Regulation in Exercise Questionnaire (BREQ) to measure the continuum of behavioral regulation in exercise contexts. The short version of IMI is specifically designed for use as a pre-test and post-test. However, it deals with competence, interest, and effort which duplicates the skills and self-efficacy tests from Cornell's Lab of Ornithology.

I chose to use the Situational Motivation Scale (SIMS) of Guay et al. (2000) in favor of other validated instruments as it is specifically designed for situational motivation. Situational motivation refers to the motivation that stems from currently being engaged in an activity (see table 6).

Table 6:Measures of the Situational Motivation Scale

Why are you currently engaged in this activity?							
1. Because I think that this activity is interesting	1	2	3	4	5	6	7
2. Because I am doing it for my own good	1	2	3	4	5	6	7
3. Because I am supposed to do it	1	2	3	4	5	6	7
4. There may be good reasons to do this activity, but personally I don't see any	1	2	3	4	5	6	7
5. Because I think that this activity is pleasant	1	2	3	4	5	6	7
6. Because I think that this activity is good for me	1	2	3	4	5	6	7
7. Because it is something that I have to do	1	2	3	4	5	6	7
8. I do this activity but I am not sure if it is worth it	1	2	3	4	5	6	7
9. Because this activity is fun	1	2	3	4	5	6	7
10. By personal decision	1	2	3	4	5	6	7
11. Because I don't have any choice	1	2	3	4	5	6	7
12. I don't know: I don't see what this activity brings me	1	2	3	4	5	6	7
13. Because I feel good when doing this activity	1	2	3	4	5	6	7
14. Because I believe that this activity is important for me	1	2	3	4	5	6	7
15. Because I feel that I have to do it	1	2	3	4	5	6	7
16. I do this activity, but I am not sure it is a good thing to pursue it	1	2	3	4	5	6	7
Codification key: Intrinsic motivation: Items 1, 5, 9, 13; Identified regulation: Items 2, 6, 10, 14; External regulation: Items 3, 7, 11, 15; Amotivation: Items 4, 8, 12, 16.							

Measuring research literacy

A self-devised measure to capture gain in understanding (research literacy) as a result of the training sessions, was adapted from a methodology suggested by Cronje *et al*. (2011) measuring scientific literacy. I added this intentionally constructed scale to measure the specific gains in research literacy for the tricot approach, which were not captured in either of the validated situational motivation or situational evaluation of citizen science scales. The measure consists of four open-ended questions which were added to the pre/post-test questionnaire in rounds two and three. The research literacy scales are based on a methodology suggested in Cronje *et al*. (2011). Literate responses received a score of 1 and illiterate or no responses received a score of 0. See table 7 for an overview of the questions.

Table 7: Scoring scheme for open-ended literacy questions

Question 40: Please tell us in your own words what it means to do a research experiment?

Literate answers (score = 1)

1. Any responses referring to the *process* of research
2. Any responses describing careful and rigorous controls
3. Any responses describing doing something from beginning to end, observing to understand things, understand how processes are done

Not literate (score = 0)

4. Any responses showing none of the above levels of understanding (to understand, to gain knowledge, to know more about things, to get to the deeper cause of something)
5. No response

Question 41: Please give us at least one reason why it is important to compare the performance of different varieties?

Literate answers (score = 1)

1. Any responses indicating a comparison with other farmers or areas (to understand how things are done in other areas, because of climatic differences in other environments, to combine understanding from others, to get a common response from many)
2. Any responses referring to within farm comparison for decision-making (to compare what works and to be able to follow it, to know which variety is the best)
3. Any responses referring to experimentation (to understand the different effects on crops, which crops have more or different pests & diseases, to see how much water different crops use, different management)

Not literate (score = 0)

4. Any responses showing none of the above levels of understanding (to have another option, to understand climate issues, for growth, to know the harvest)

5. No response

Question 42: Please give us at least one reason why it is important to set up experimental plots?

Literate answers (score = 1)

1. Any responses indicating towards comparisons (understand which variety is best, does well, differentiate what can help me in the shortest time, to know what is good or bad)
2. Any responses indicating the use of data (find out if I can experiment with different crops, maintain good data, to be your own researcher)

Not literate (score = 0)

3. Any responses showing none of the above levels of understanding (to understand, to gain knowledge, to know more about things, to get to the deeper cause of something)
4. No response

9.2.4 Qualitative data collection

Qualitative data collection comprised of three methods: cultural probes, observations collected during the iterative design process, and farm visits to a selection of the participants.

Cultural probes

Cultural probes are materials that designers create and send to end-users without much guidance on how they should use the materials. They are a popular approach in codesigning to solicit inspiration from end-users. They can take any shape or form and usually consist of postcards, workbooks, or cameras with some provocations to motivate people to use the materials (Gaver *et al*., 1999). Cultural probes are left with the end-users to use at their convenience and return to the designers after some time (Sanders and Stappers, 2014).

I had initially intended to design a cultural probe as an artifact to collect insights from end-users in this study, mainly to find out how and what type of data participants in the trials would like to collect themselves. However, the distribution of the probing kit became an important ethical consideration and therefore, I took a pragmatic stance on the design of the probe. The design experiment was set up to teach participants about the tricot research approach, and therefore participants should also be allowed to actually participate. Since there was no indication that another tricot research cycle would start in the near future, I provided them with the means to start a tricot trial on their own account, using the information from the training and a booklet included in the package which contained the necessary information about the research process. The cultural probe was designed to represent a trial package and allowed for the testing of different varieties of common vegetables. The data collection booklet was written in the local language Kikamba[7]. I indicated that if they were to provide the data through SMS then I would pool all the data received and send back this information using SMS messages. All participants in the design experiment received an experimental test kit (see figure 77).

Figure 77: Contents of the probing kit used in the design experiment

[7] Kikamba is a bantu language spoken by the Kamba tribe in Kenya

These ‘experimental kits’ contained three labeled seed packages, a data collection booklet, a booklet for the identification of common pests and diseases in vegetables, and contact details and instructions for a wefarm, an SMS-based agro-advisory service run by farmers. The data collection booklet consisted of a short visual explanation of the process, five questions comparing (best versus worst) crops for different physiological traits, instructions on how people can share their data with the researchers, open-ended questions on which vegetables they would like to grow again and two evaluation questions to solicit feedback on their perceptions of the trials. The booklet also contained templates for collecting notes on planting, weeding, water use, rainfall, pest and diseases, harvesting, marketing, and included two recipes with suggestions on how to prepare a meal with the crops included in the trials. The data collection booklet was written in the local language Kikamba.[8] The experimental kits were handed out to participants during the training with a short explanation of its contents and purpose.

Iterative design of training activities

Three cycles of formative, generative and evaluative research were carried out, each round designed to fulfill a different purpose. See table 8.

Table 8: Overview of different rounds of data collection

Time	Activity	Design phase	Design method	Type of research
July 2019	Briefings sessions	Planning / scoping	Participant observation	Formative
August 2019	Round 1 of Designing training activities	Exploring / Design implications	Immersive and explorative research	Formative
October 2019	Round 2 of Designing training activities	Early prototype Iteration	Participatory and generative design	Generative
October 2019	Round 3 of Designing training activities	Evaluation and Refinement	Iterative testing and feedback	Evaluative

[8] Kikamba is a bantu language spoken by the Kamba tribe in Kenya

The intervention consisted of iteratively designing training activities using participatory workshops, in this research referred to as training sessions. The 'treatment' consisted of a 2-3 hour introduction aimed at increasing participants' understanding of the tricot research process. The activity in the treatment group (n = 70) focused on the *tricot process*, the reasons behind data collection, and what feedback they can expect, or what their role as citizen scientist is. The activity in the treatment-as-usual control group (n = 32) focused on how to *set up different types of kitchen gardens* and provided a brief explanation of the tricot research process and the standard data collection format. In addition to the treatment and control groups, I conducted a post-test with current tricot users (n = 42) across 4 different locations in the same study area.

The observations during fieldwork combined with precedent and prior experience led to a set of design considerations. Prototypes of instructional activities were subsequently developed during three rounds of fieldwork. Each training day constitutes one iteration. Changes were made to the training set-up and the activities between each training day, followed by a more thorough redesign of the training set-up and activities between the different rounds of fieldwork.

The first round of fieldwork training was provided by Joy Wanza (local facilitator) and the author together with an extension officer. In rounds, two and three of the design experiment (iterations 4-8) training was provided by the author together with a local translator who acted as a facilitator. At the same time and in the same location, Joy Wanza provided a training-as-usual to the control group. Three different translators were used during the fieldwork. Training sessions took place in the open air at farmers' homesteads, in empty food storage halls, and church buildings. Each session lasted around 4 hours. A participant information sheet and a consent form were provided in English and translated into the local language in front of the groups. After receiving consent for their participation we started the training activities. This section presents an overview of these iterations with a description of the activities that took place, methods or tools used, observations, and conclusions.

The design of the training sessions started with observations made during a training-as-usual for ongoing tricot research. The training-as-usual session was carried out by the field officer

(Joy Wanza) with the help of a local extension officer. There was no set protocol for the training. Most of the training was devoted to the practical demonstration of different types of planting kitchen gardens by the extension officer. Joy Wanza briefly explained the different steps in the research process using the data collection template as a visual aid during the registration process and distribution of the trial package.

Figure 78: Tricot training session on 11 July 2019

Farmers are participating in a regular tricot training session in Makueni County on 11 July 2019. Here, extension officers demonstrate how to set up different types of kitchen gardens promoting water retention and soil conservation. Here the participants are sealing a small planting pit with a waterproof liner to preserve water. Photo by author.

In the design phase that followed, existing training materials were studied. Experiences with farmer experimentation, especially with data collection were compiled from my own research experience and a survey amongst tricot practitioners. Precedent was collected in farmer training (Sthapit, Joshi and Witcombe, 1996; Witcombe *et al*., 1996; Khisa, 2004; Boef and Thijssen, 2007; Mercy Corps, 2019), health literacy (Kripalani and Weiss, 2006; Kripalani *et al*., 2008; Ba *et al*., 2013; Afolabi, 2014), the use of visual aids for low-literacy (Dowse, 2004; Houts *et al*., 2006; Seligman *et al*., 2007; Smith *et al*., 2008; Kodagoda, 2012; Negarandeh *et al*., 2013; Garcia-Retamero and Cokely, 2017), how to measure scientific literacy (Crall *et al*., 2011; Cronje *et al*., 2011).

Round one consisted of formative research in the design of prototypes and tools used as instructional activities. In three separate training sessions (iterations 1-3) the field agent responsible for implementing *tricot* trials (Joy Wanza) demonstrated how to set up kitchen gardens with help of extension officers. Learning goals in round one focused on exploring how people learn, what expectations participants might hold, and how participation could benefit them. The training sessions included the treatment group and the current tricot users. The training activities focused on how to design training activities that would engage rural farmers in the design process and move from instruction to a more practical approach by mimicking or demonstrating the actual research process. Activities included a demonstration of the research process using the actual crops and observations cards of *tricot* trials, data compilation, and explaining the 'wisdom of the crowd' principle. Part of the underlying ideology of the tricot research approach is that the opinions of many individuals can lead to more reliable data than the opinions from a smaller group of experts.

(1) I set up a demonstration on how to make observations as part of the tricot research process. This did not work well. Participants were busy filling the cards with each other, and did not pay too much attention to the crops. Perhaps familiarity with the crops hindered the demonstration.

(2) The visualisation of feedback on sheets of paper taped to the wall, did work well. However, we need to go one step further than just presenting the data. What data interpretation exercise can I design to show them how to compile, read and use the data?

Figure 79: Observations during the first round of iterative design sessions

Observations during the first round of iteratively designing training sessions. The photo was taken by the author on 6 August 2019 in Makueni County, Kenya

The lessons learned in the first round of formative research were used to redesign the training sessions for the second round of fieldwork. I found that the explanation of the wisdom-of-the-crowd principles using visual aids helped to clarify the purpose and value that tricot might bring to its participants. Participants indicated they liked the fact that they were able to share knowledge and learn from others. Some of the codesigning activities worked well: rather than go into the field with preconceived ideas or base materials on previous experience, it helps to leave things open for suggestions as you continue to develop the materials, spending the extra time in the front end designing useful approaches.

Round two consisted of generative research and exploration characterised by trying to vary the levels of engagement required from participants in the training activities. For the second round of fieldwork, I looked at the principles of co-design and experience prototyping (Buchenau and Suri, 2000; Brown, Reeves and Sherwood, 2011; Klann and Geissler, 2012; Sanders and Stappers, 2014). The design of instructional activities was inspired by experience prototyping (Buchenau and Suri, 2000) aiming to explore design ideas with varying levels of investment required from participants ranging from instruction to co-creation, and from abstract instructions to hands-on demonstrations. I designed a generative toolkit of interactive and engaging training materials to allow the facilitator and the participants to act as codesigners of the training activities. The toolkit consisted of card sets, stickers, and hand-outs that could be used in multiple activities. A training manual gave suggestions for different activities. The purpose of this generative toolkit was to help me explore which training activities work well for our context. Learning goals in round 2 of the fieldwork focused on *how* to conduct basic experiments by using controls and comparisons, and comparability in research or collecting good quality data. It also focused on *why* rigorously conducting research is beneficial. If everyone does the same basic experiment, data can be shared and compared with others. It offers benefits of group learning even when experimenting individually and offers benefits beyond the findings of their own research. In terms of design, more emphasis was put on the visualization of the research process and incorporating visual aids and games into the training activities and whether training activities can be redesigned to include more co-design elements and evaluation. Activities in round two included an explanation of the value statement of *tricot* trials (‘*you only have time to test a few crops in one season, yet through tricot, you can learn about the performance of a much larger group of crops in a group effort*’), the different steps in the research process, basic research skills and setting up experimental plots, and conducting a ‘chocolate’ experiment. A chocolate experiment was first designed to explain the principles of tricot research to implementers of the approach in Latin America (J. Van Etten, pers. Comm. 2015). Participants in tricot training sessions are asked to rank three pieces of chocolate according to taste, smell, or color with each receiving a different combination of chocolates. This data is compiled and feedback is provided on which of the chocolates was ranked highest in the group. This activity can easily be carried out under field conditions, although in subsequent rounds I substituted chocolates for cookies and candy as the chocolate would usually melt before carrying out the activity. Other activities included a comparison of different formats of feedback delivery (orally and by note-taking and visualizing what insights participants gave me). The wisdom of the crowd principle was explained using an example of ‘guessing the weight of the bull’. The experimental test kit package was explained in detail during the training, as this in itself turned out to be a useful training aid.

Figure 80: Making observations for different traits using a cookie tasting experiment

The take-aways from the second round of training sessions were to improve the quality of the training materials and instructions to the facilitator to develop the codesigning activities. I aimed to revise the learning goals and make the purpose of the research (e.g. The 'why we want you to plant a certain way, make observations a certain way) more clear. The generative toolkit with materials was used in a very simplistic manner, and it would be better to add more content and to structure the activities more (e.g. More preparation needed to design the materials beforehand). I restructured the training to include an assessment of the level of understanding for each activity in the training session adding more room for discussion and talking, rather than focusing on co-design activities.

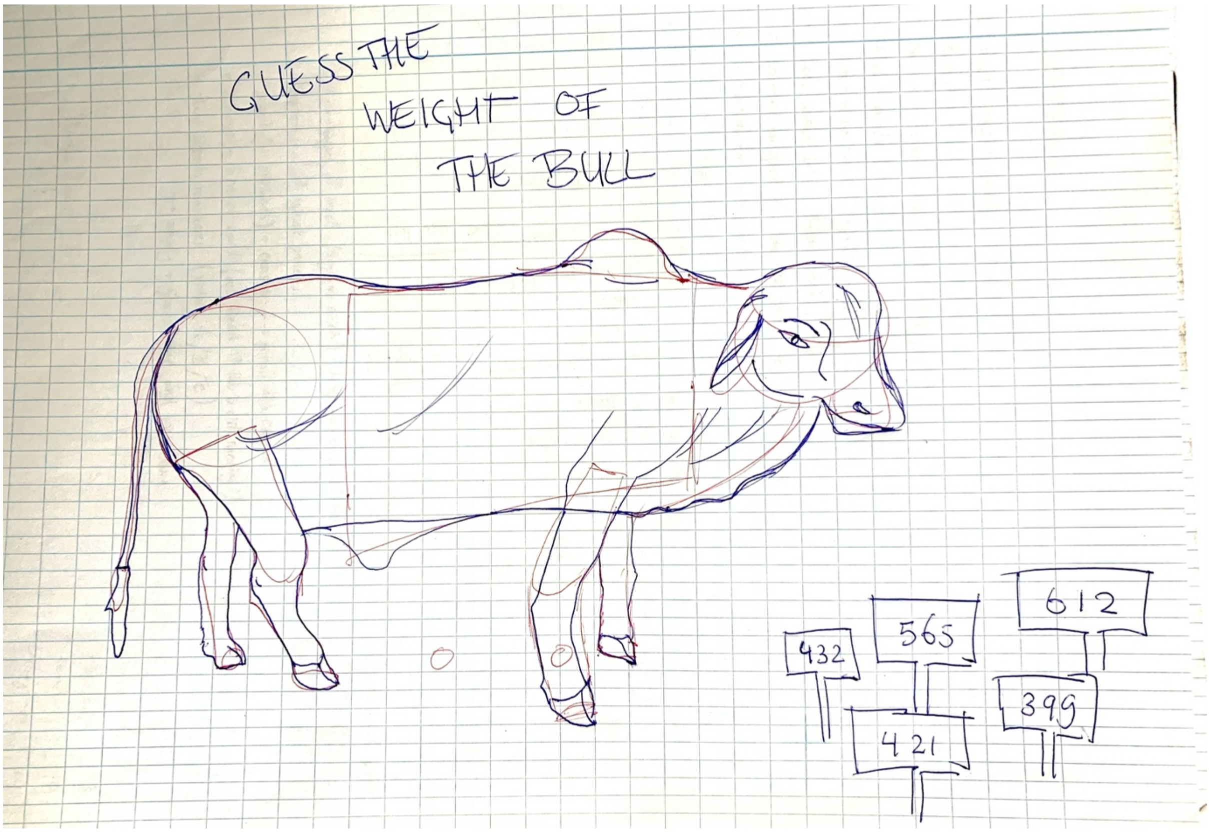


Figure 81: Template used to explain wisdom-of-the-crow principles

I repeated the same type of exploration in round three with more emphasis on 'why' conducting research more rigorously offers benefits and what these benefits are and whether we can include more evaluative elements into the design of the training activities. Higher fidelity training materials and handouts were designed to be less simplistic by adding more context and content and to be more interactive in terms of 'getting people out of their chairs' by letting them fill forms, put sticky notes, etc. More time was spent preparing the translator/trainer for the activities, which improved the way the activities and their purpose were explained to the participants. Separate activities were developed for each step in the research process and using the probing package as a guide. Basic components of conducting research, how to make observations, and random distribution were explained. A candy tasting experiment was used to demonstrate how to make observations and collect and record data, how data is compiled and made available to all participants.

(3) “Joy Wanza spent a large part of her time explaining the kitchen garden experiment. This is part of her work at Lutheran World Relief and she has been coached by the organization to do so. Participants in the control group are used to receiving agronomic advice and the training in the different kitchen garden types provides them with actionable and useful information. This is in stark contrast with the type of information or training provided as part of the tricot research approach. Here there are no direct benefits other than receiving the seeds. Logically our training sessions increased trainees’ understanding of tricot research principles, but I don’t know if this then leads to higher scientific literacy or a greater understanding of the ‘why’ of doing this research.” *Field notes 15 August, 2019*

Figure 82: Observations made by researcher during training event

The redesigned codesign activities worked better in round three, however, we missed the opportunity to provide clear takeaways and this might have led to more confusion amongst participants and affected their level of understanding of the tricot research process. The activities seems too simplistic and on several occasions led us (myself and the facilitator) to switch from codesign to provide instructions. After the training session, a majority of the participants could not explain the principles of distributed experiments or their benefits.

Farm visits

Farm visits offered a final measure to assess to what extent participants used the information from the training activities and the experimental test kit. Participants were purposefully selected to represent each iteration[9] and treatment group, occasionally substituting farmers with farmers from the same subgroup if they were unavailable during the time of the interview. Farmers were visited at their homes, and interviews took place in the kitchen gardens or nurseries, observing their methods of planting, and asking questions to assess their level of understanding (“to what level have you used the trial package?”, “can you explain the different steps in the tricot research approach?”, “how do you intend to observe your crops?”), and inquiries into the perceived benefits of the experiment (“what are you learning?”, “what do you want to learn from others?”). Data were collected from a total of 29 participants and coded by hand in the first round of coding directly after fieldwork and

[9] With the exception of iteration group 3 who did not receive a experimental test kit and iteration group 4 who received their test kits after fieldwork had ended.

further categorised using NVIVO in the second round of coding. After coding and categorizing the data, frequencies were computed using Microsoft Excel. This data provided insights into participants' level of understanding and validation in terms of participants' behavior (e.g. If what people say they did was what they did.

Figure 83: Different implementations of tricot trials during the farm visits

9.3 Results/Findings

9.3.1 Data analysis

Data entry

I completed the double data entry between 7 August and 6 November 2019, with three weeks minimum in-between the first and the second data entry. The data entry files were compared using MS Excel and differences were verified using the paper questionnaires.

Quantitative data analysis

Quantitative pretest and posttest data were screened for inconsistencies, missing values, outliers, and extreme data. Participants who filled a pretest and were unavailable to complete a posttest survey were excluded (n = 4). Illiterate participants who received help in filling their questionnaires were observed for their participation. In two cases the questionnaire was filled on their behalf by the lead farmer without much interaction from the participant. In such cases, the questionnaires were marked, and their data was omitted (n = 2). Participants falling within a 10% range of the maximum score (=all maximum values combined) and failing to notice the reverse-scored questions were excluded (n = 6). The reason is that if participants fail to notice any reverse-scored questions and do not vary in any of their answers, then it is likely that the participants failed to take the test seriously and filled a maximum score for each question.

The average completion rates of the questionnaires were 79% for the pretest and 90% for the posttest. The majority of missing values fall within 1-4 omissions per questionnaire (28% of 159 data points). Participants with more than 4 omissions in the questionnaire were excluded (n = 2). Questionnaires with less than 4 omissions were included in the analysis and left blank. The total missing values included in the analyses constitute less than 2% of the data (table 9).

Table 9: Percentage of missing values left blanc as part of the total values

Missing values	**Total**
Valid	6128
Missing	73
Percentage missing	1.19%

Table 10: Summary of issues considered in the analysis of a pretest and posttest survey

Data stage	**Sources of problems**	**Nr of excluded datapoints**
Data collection	Illiteracy issues	1
	Only filled the pretest and did not complete the posttest	5
Questionnaire	Extreme scores AND failed to notice reversed scored items	6
	More than 4 missing values (> 4)	2

Database	Inadvertent duplications during database handling	1

The analysis of the data was carried out with IBM SPSS 26 (IBM Corp, 2019) and IBM SPSS 28 (IBM Corp, 2021).

9.3.2 General results

Data description

Quantitative data was collected using a pre/post-test design including two separate control groups. The outcome variables (dependent variables) are *amotivation, skills for science inquiry,* and *research literacy*. Amotivation and skills are continuous variables with repeated measures (pre/post-test scores). Research literacy is a categorical variable representing the sum of three sets of binomial data with repeated measures (pre/post-test scores). The total score for research literacy consists of the sum of each question scored as "0" which indicates non-literary and "1" which indicates literacy.

There are two main independent variables: treatment groups and iterations of the training event. The *treatment group* variable consists of three levels: a control group (received training-as-usual), a treatment group (received training aimed to increase research literacy), and on the third level a second control group consisting of previous tricot participants (received no training, but experienced the research process before). The second independent variable consists of eight *iterations* taking place on a different day, using different training materials and different groups (participants in one group do not participate in another group).

Several other independent variables are used in the analyses; categorical values such as gender, level of education, prior research experience, and continuous variables, for example, age.

Sample characteristics

The study was carried out on a sample of 159 participants who voluntarily participated in the experiment. Fifteen participants were excluded from the original sample due to incomplete or erroneous questionnaires. The total number of pretest-posttest datapoints remaining is 144: 70 participants were exposed to the training (treatment group) and 32 comprised of the control group. In addition, 42 current tricot users were asked to complete the survey (posttest only), as a benchmark for measuring motivation and self-efficacy levels in actual users.

Table 11: Number of pretest-posttest questionnaires

	PRETEST	POSTTEST
Treatment group	70	70
Control group	32	32
Tricot user group	-	42
	102	144
Excluded datapoints		15

n=159

Table 12: Demographic characteristics

Demographic characteristics (n = 144)		*Total (%)*	*Tricot (%)*	*Treatment (%)*	*Control (%)*
Age	18-29 years	*9%*	7%	6%	19%
	30-39 years	*24%*	17%	29%	25%
	40-49 years	*22%*	21%	23%	19%
	50-59 years	*23%*	31%	19%	22%
	60-69 years	*16%*	19%	14%	16%
	70 years and over	*6%*	5%	10%	0%
Gender	Female	*81%*	81%	81%	78%
	Male	*19%*	19%	19%	22%
Education	None	*11%*	10%	13%	9%
	Primary	*63%*	76%	61%	50%
	Secondary	*19%*	10%	19%	34%
	Above	*6%*	5%	6%	6%
	(Blanks)	*1%*	0%	1%	0%
Research experience	No prior experience	*41%*	14%	51%	53%
	Participated once	*33%*	48%	29%	22%
	Participated more than once	*26%*	38%	19%	25%
Role in group	Chairperson	*9%*	12%	6%	13%
	Lead farmer	*2%*	5%	1%	0%
	Member	*75%*	64%	83%	72%
	Secretary	*6%*	10%	3%	6%
	Treasurer	*4%*	5%	4%	3%
	Vice chairperson	*1%*	0%	0%	3%
	(Blanks)	*3%*	5%	3%	3%

We purposively sampled for a 80% female (n = 116) and 20% male (n = 28) participants ratio. *Tricot* experiments focused on kitchen gardens which are traditionally kept by women in our location, and a less controlled sampling method would have led to skewed results. All participants (100%) in the survey are members of a farmer group. 30% of the participants take on additional roles in the group, f.e. Lead farmer, chairperson, secretary, or treasurer. Other than the lead farmer who more frequently interacts with staff from Lutheran World Relief, and might be more exposed to research, there is no difference between a group member and a chairperson in terms of exposure to *tricot* research.

Descriptive statistics

Descriptive statistics for each measure are presented in table 9.9. Pre/post-test differences are small with significant differences between the pre/post-test level scores of amotivation, skills for science inquiry, and research literacy (see figure 84). Pre/post-test gains are significant for amotivation, self-efficacy for science, self-efficacy for citizen science, interest, skills, and research literacy. Effect sizes are small, except for moderate effect size for research literacy (see table 9.9).

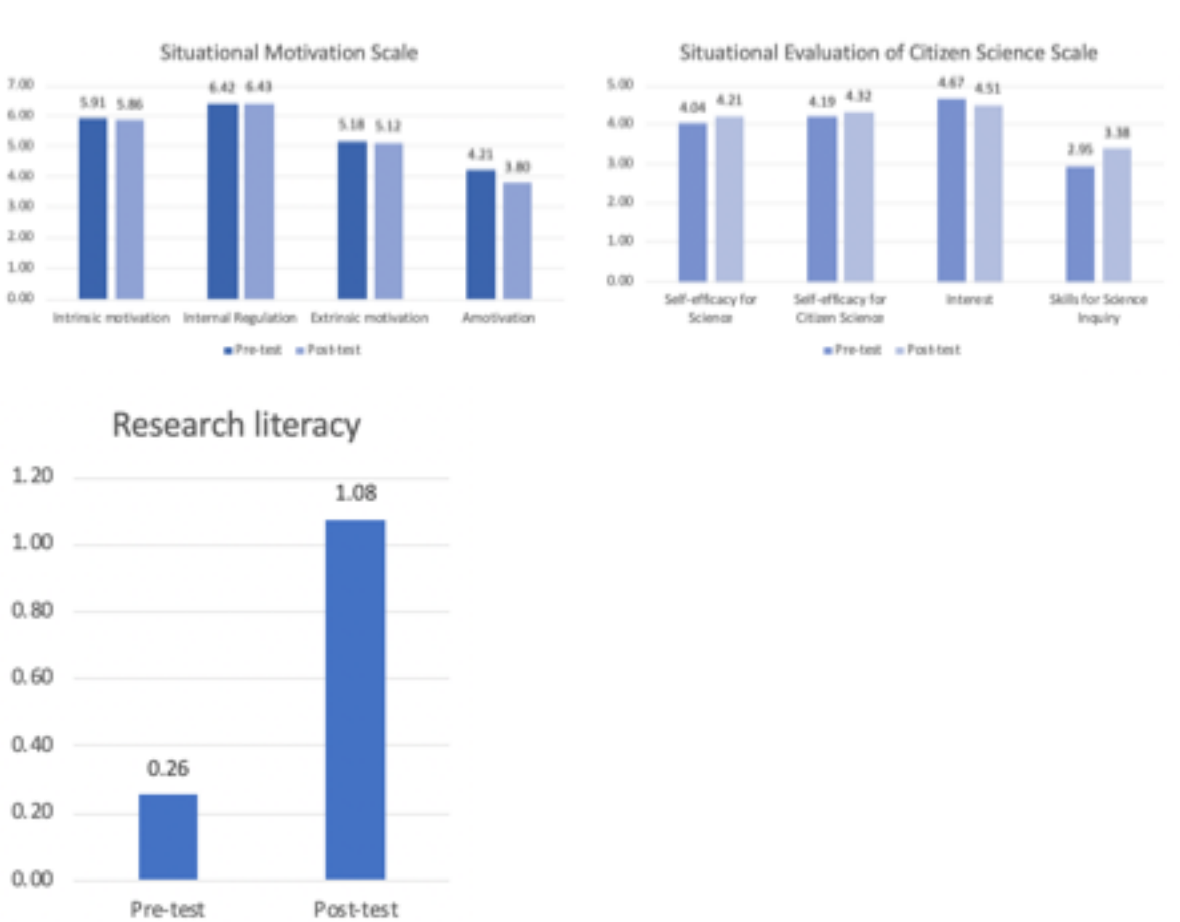


Figure 84: Pre/Post-test gains for all measures in the treatment and treatment-as-usual control group (n=102)

Table 13: Descriptive statistics and effect sizes for measures included in the pre/post-test survey

		Pre-test				Post-test				Effect sizes		
	n	Mean	SD	Min	Max	Mean	SD	Min	Max	Z *	*p*	*r* **
Intrinsic motivation	102	5.91	0.87	3.5	7	5.86	0.83	4	7	-0.596*	0.551	-0.042
Internal Regulation	102	6.42	0.76	3	7	6.43	0.65	4.75	7	-0.018*	0.985	-0.001
Extrinsic motivation	102	5.19	1.26	1.75	7	5.12	1.09	2.25	7	-0.672*	0.502	-0.047
Amotivation	102	4.21	1.63	1	7	3.80	1.81	1	7	-2.216*	0.027	-0.155
Self-efficacy for Science	102	4.04	0.76	1.87	5	4.21	0.60	2.75	5	-2.399	0.016	-0.168
Self-efficacy for Citizen Science	102	4.19	0.65	2.5	5	4.32	0.56	3	5	-2.224	0.026	-0.156
Interest in Science and Nature	102	4.67	0.47	3	5	4.51	0.45	3	5	-3.007*	0.003	-0.211
Skills for Science inquiry	102	2.95	1.23	1	5	3.38	1.29	1	5	-2.59	0.010	-0.181
Research literacy	66	0.26	0.59	0	3	1.08	0.87	0	3	-5.582	<.001	-0.486

** *z-score based on positive ranks*
** *small effect: r < 0.03, moderate effect: r = > 0.03, large effect: r = > 0.05*

I report the Cronbach's Alpha coefficient of reliability and alpha coefficients (Cronbach, 1951) on standardised items as I used two different response scales (the SIMS scales use a 1-7 response scale and the DEVISE scales uses a 1-5 response scale).

Table 14: Cronbach alpha values for all measures

Scales (measured on a 7-point likert scale)	N of Items	Mean	SD	Cronbach's Alpha *
Intrinsic motivation	4	5.91	3.475	0.409
Internal Regulation	4	6.42	3.042	0.558
Extrinsic motivation	4	5.19	5.042	0.61
Amotivation	4	4.21	6.538	0.652
Scales (measured on a 5-point likert scale)	**N of Items**	**Mean**	**SD**	**Cronbach's Alpha ***
Self-efficacy for Science	4	4.04	3.022	0.584
Self-efficacy for Citizen Science	4	4.19	2.596	0.477
Interest in Science and Nature	6	4.67	2.795	0.727
Skills for Science Inquiry	9	2.95	11.046	0.915

* *Based on Standardized Items*

Cronbach alpha coefficients on the SIMS scales are low, despite it being a widely validated instrument for measuring situational motivation across a range of activity contexts. The SIMS sub-scale reliability commonly ranges between .70 and .90 (see Guay *et al*., 2000; Standage *et al*., 2003). Similarly, the self-efficacy scales derived from Phillips *et al*. (2018) have low reliability with values < 0.6. Low scores on reliability tests show us how well participants can be differentiated by their scores. If test-takers differ significantly in their abilities, λ-2 will be high and the error will be low. Explanations for low internal consistency could be sought in the small sample size (<250), and in insufficiently validated translations which could have introduced biases and led to the loss of original meaning (Martín-Albo et al., 2009) or unfamiliarity with research and surveys in our population.

For the analysis of pre/post-test data, I will focus on amotivation which serves as a reversed measure of motivation and skills for science inquiry as a measure of self-efficacy as it is the only scale of the SIMS that has near decent scale reliability. The other measures reported in table 14 are not used in the analysis as the internal consistencies exceeded acceptable levels of internal consistency. The measure of research literacy is an intentionally designed measure for participants' level of understanding of the tricot research process and is not validated other than through this research. The three questions of this measure cover different aspects of this understanding and as such, I expect low internal consistency and do not report Cronbach alpha for this measure.

9.3.3 The linkages between research literacy and motivation or self-efficacy

To explore the correlation between research literacy and levels of motivation or self-efficacy, I look at the pre/post-test changes in motivation, self-efficacy, and research literacy using the following hypotheses:

Hypothesis a:
Pre/post-changes in motivation (= amotivation measure reversed) are positively correlated with pre/post-changes in research literacy (= qualitative measure of understanding)
In the lumped treatment and treatment-as-usual control group.

Hypothesis b:
Pre/post-changes in self-efficacy (= SKILLS measure) are positively correlated with
Pre/post-changes in research literacy (= qualitative measure of understanding)
In the lumped treatment and treatment-as-usual control group

Gain scores were calculated (posttest - pretest scores) for every data point. The correlation analysis tells us if research literacy has a causal effect on the increase in self-efficacy scores or decrease in amotivation in the posttest results. I also report the effect sizes to quantify the strength of this potential relationship.

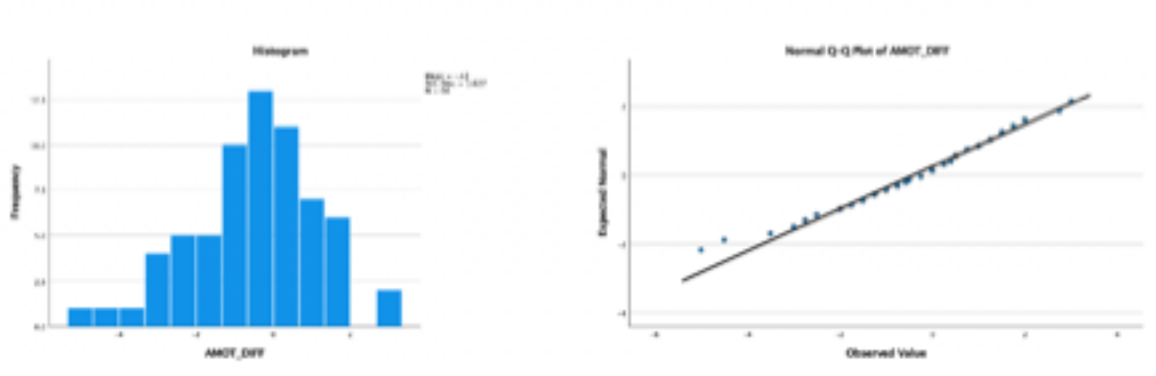


Figure 85: Histogram and QQ plots indicating normally distributed data for amotivation (n=66)

Normality analysis included skewness and kurtosis z-values, the Shapiro-Wilk test results, histograms, normal Q-Q plots, and box-whisker plots (Shapiro and Wilk, 1965; Doane and Seward, 2011). The data were normally distributed for *amotivation* W(66) = .981, p = .399. For both the *skills* and the *research literacy* the visual inspection of histograms, QQ plots, and boxplots indicated a near-normal distribution (see figure 85). However, I found significant results on the Shapiro-Wilk test for *skills* W(66) = .959, p = 0.029 and *research literacy* W(66) = .876, p = <0.001.

This revealed rejection of the normality hypothesis in favor of non-parametric tests and led to the use of Spearman's rank correlation coefficients over the use of Pearson's correlation coefficients. I assume that no correlation exists if values are near ± 0, correlations below 0.29 are considered weak, between 0.30 and 0.49 moderate, between 0.50 and 1 strong, and nearing ± 1 high degree of correlation perfect. This is similar to negative values (Spearman, 1904).

Spearman's rho for the correlation between *amotivation* and *research literacy* reveals a non-significant result, r(66) = -.21, p = .085. I do not have enough evidence to suggest a correlation between research literacy and amotivation exists. Spearman's rho on the gains in pre/post-test scores reveal that there is a moderate positive correlation between *skills* and *research literacy,* r(66) = .34, p = .005. A positive correlation indicates that if research literacy increases, self-efficacy will also increase.

9.3.4 Does iterative design impact the effectiveness of training activities?

By varying the training activities and improving on the design based I was able to collect data on which type of training activities impact different motivational measures. Here I examine whether *amotivation,* perceived *skills for science inquiry,* and *research literacy* increase over time as the training material evolves.

I performed a one-way independent analysis of variance (ANOVA's), including Levene's test of variance and Welch's test whenever equal variances could not be assumed. In the following section, I present the results of the quantitative data analyses.

Impact of Iterative Design on amotivation

A) There are pre/post-test gains in motivation (= amotivation measure reversed) in the treatment group.

I first examine if there are pre/post-test gains in motivation in the treatment group. Normality analysis included skewness and kurtosis z-values, the Shapiro-Wilk test results, histograms, normal Q-Q plots, and box-whisker plots (Shapiro and Wilk, 1965; Doane and Seward, 2011). Skewness and Kurtosis are within bounds, however, the Shapiro-Wilk test shows a significant result for both the pre-test (W = 0.96, p-value =.013) and the post-test (W = 0.94, p-value =.003) indicating that the data is not normally distributed. Visual inspection of the histogram and QQ plot confirm non-normality. Therefore, I reject the normality hypothesis in favor of non-parametric tests.

Table 15: Descriptive statistics for amotivation

						Shapiro Wilk		
Measure	**n**	**Mean**	**SD**	**Skewness**	**Kurtosis**	*W*	*df*	*p-value*
Pre-test	70	4.01	1.77	0.287	0.566	0.955	70	0.013
Post-test	70	3.48	1.8	0.287	0.566	0.941	70	0.003

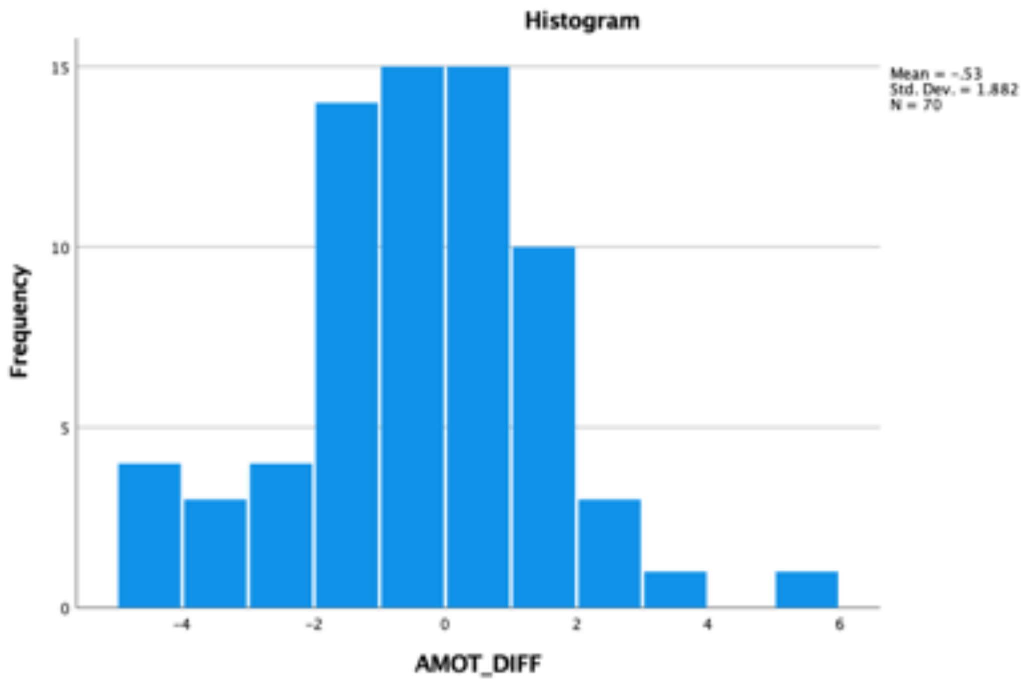


Figure 86: Histograms confirming normality in pre/post-test gain scores for amotivation

The non-parametric equivalent of a paired samples t-test is the Wilcoxon Signed-Rank test. I want to test whether there are significant differences in amotivation between the pre-test and the post-test results in the treatment group. The Wilcoxon Signed-Rank test revealed that the intervention elicited a statistically significant change (Z = -2.273, p = 0.023) in *amotivation* for participants in the treatment group. I calculate the effect size by dividing the Z value with the square root of N *(n = 7*0) as suggested in Pallant (2016: p.581). Amotivation decreased from pre-test (*Md* = 4.01) to post-test (*Md* = 3.48) with a small effect size (r = .27). For 40 participants amotivation has declined after the treatment. For 23 participants levels of amotivation went up after the training and for 7 participants their reported levels of amotivation did not change before or after the intervention.

B) Pre/post-test gains of motivation (= amotivation measure reversed) are higher in succeeding iterations in the treatment group.

The interventions consisted of iteratively designed training events in which different groups participated. The assumption is that through iterative design the training materials and set-up would gradually increase in effectiveness, based on lessons learned in prior sessions. To test this assumption I conduct a one-way ANOVA to measure the pre/post-test gains of motivation in succeeding iterations in the treatment group. The eight different iterations of the training activity are used as the independent variable and amotivation gains scores form the dependent variable. Levene's test was used to assess the homogeneity of variance which is one of the assumptions of group mean comparisons. Levene's test indicated equal variances ($F = 1.297$, p-value = 0.267) and the assumptions for a one-way ANOVA are met. An analysis of variance (ANOVA) revealed significant between-groups differences for amotivation, F (7,62) = 2.375, p = 0.032, d = 0.21. However, pre/post-test gains of motivation are not statistically significantly higher in succeeding iterations but show a random distribution across the different iterations.

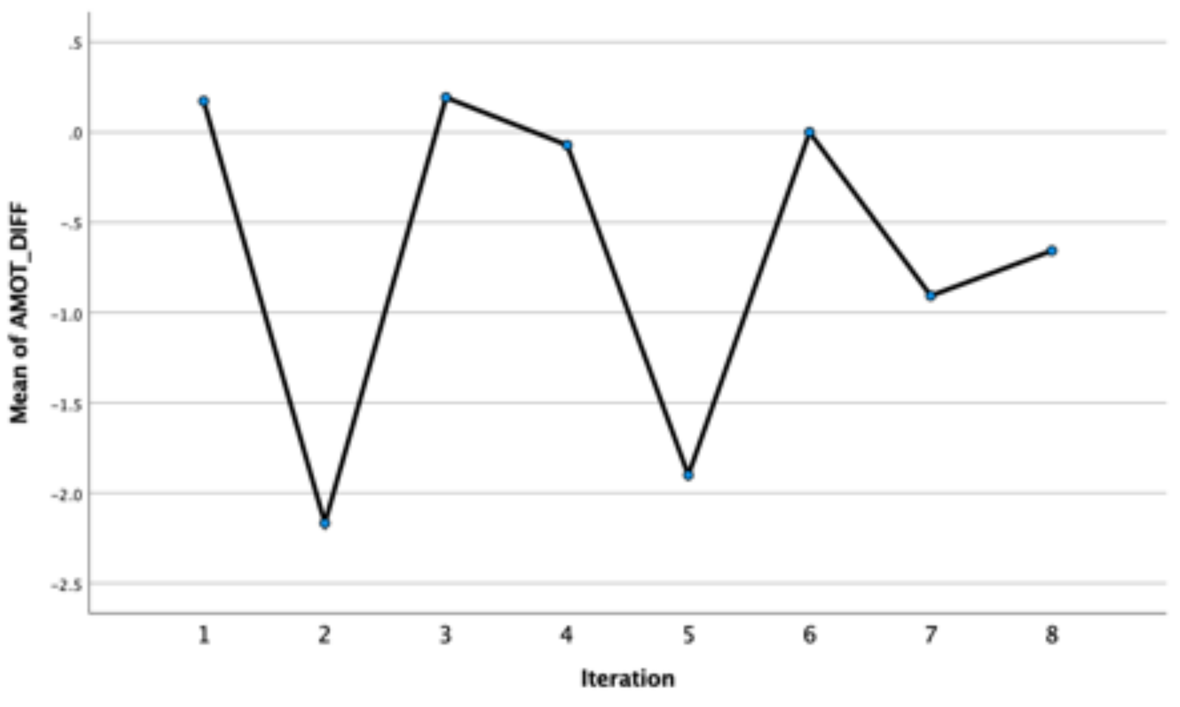


Figure 87: Differences in amotivation gain scores across different training iterations

C) Post-test levels of motivation (= amotivation measure reversed) are higher in the final treatment group than in either control group.

I compare the post-test scores for amotivation of the treatment group with post-test scores for amotivation in the treatment-as-usual control group in iteration 8. And I compare the post-test scores for amotivation of the treatment group with the post-test scores of the tricot users control group. The assumption for normal distribution of the data is not met for the tricot users control group ($W = 0.89$, p-value = <.001). Levene's test of homogeneity of variances shows a rejection of the null hypothesis (p-value = <.001) and suggests the use of a non-parametric equivalent for a one-way ANOVA.

Table 16: Amotivation scores for final treatment and tricot users

Measure	n	Mean	SD	Skewness	Kurtosis	Shapiro Wilk		
						W	*df*	*p-value*
Tricot users	42	3.924	2.182	0.365	0.717	0.892	42	<.001
Control group	6	3.541	0.797	0.845	1.741	0.942	6	0.667
Treatment group	8	2.788	0.776	0.752	0.752	0.924	8	0.463

Instead, I opt for using Welch's ANOVA which doesn't assume equal variance between the three groups. I compare the mean score of the treatment group (n = 8) to the mean score of the treatment-as-usual group (n = 6) in the final training session (iteration 8) and the tricot users group (n = 42). Normality tests indicate that the treatment and treatment-as-usual control groups have a normal distribution, yet the control group consisting of tricot users (n = 42) does not. Levene's test indicated unequal variances (F = 14.621, p = <.001). I use Welch's ANOVA which shows that there is no statistically significant difference (F = .629, p = .545) for amotivation between any of the three groups. Levels of amotivation do not significantly differ between the control group and the treatment group, nor does the data indicate that there is a statistically significant difference between the two groups who received intervention A or intervention B and the group of experienced tricot users.

Impact of Iterative Design on self-efficacy

A. There are pre/post-test gains in self-efficacy (= SKILLS measure) in the treatment group.

I first conduct the normality analysis on the pretest and posttest scores of the *skills* variable. Skewness and Kurtosis are within bounds (see table 11.7). The Shapiro Wilk shows significant results for the pre-test (*W* (70) = 0.94, p-value = .002) and the post-test (*W* (70) = .92, p-value = <.001), indicating that the data is not normally distributed.

Table 17: Descriptive statistics for skills for science inquiry for the treatment group

Measure	n	Mean	SD	Skewness	Kurtosis	Shapiro Wilk		
						W	*df*	*p-value*
Pre-test	70	2.919	1.212	0.287	0.566	0.940	70	0.002
Post-test	70	3.091	1.327	0.287	0.566	0.918	70	<0.001

The histogram showing pre-test scores has a positive skew, the post-test shows a bi-modal distribution. The QQ plots for the pre-test and the post-tests show some deviation. Therefore, I reject the normality hypothesis in favor of non-parametric tests.

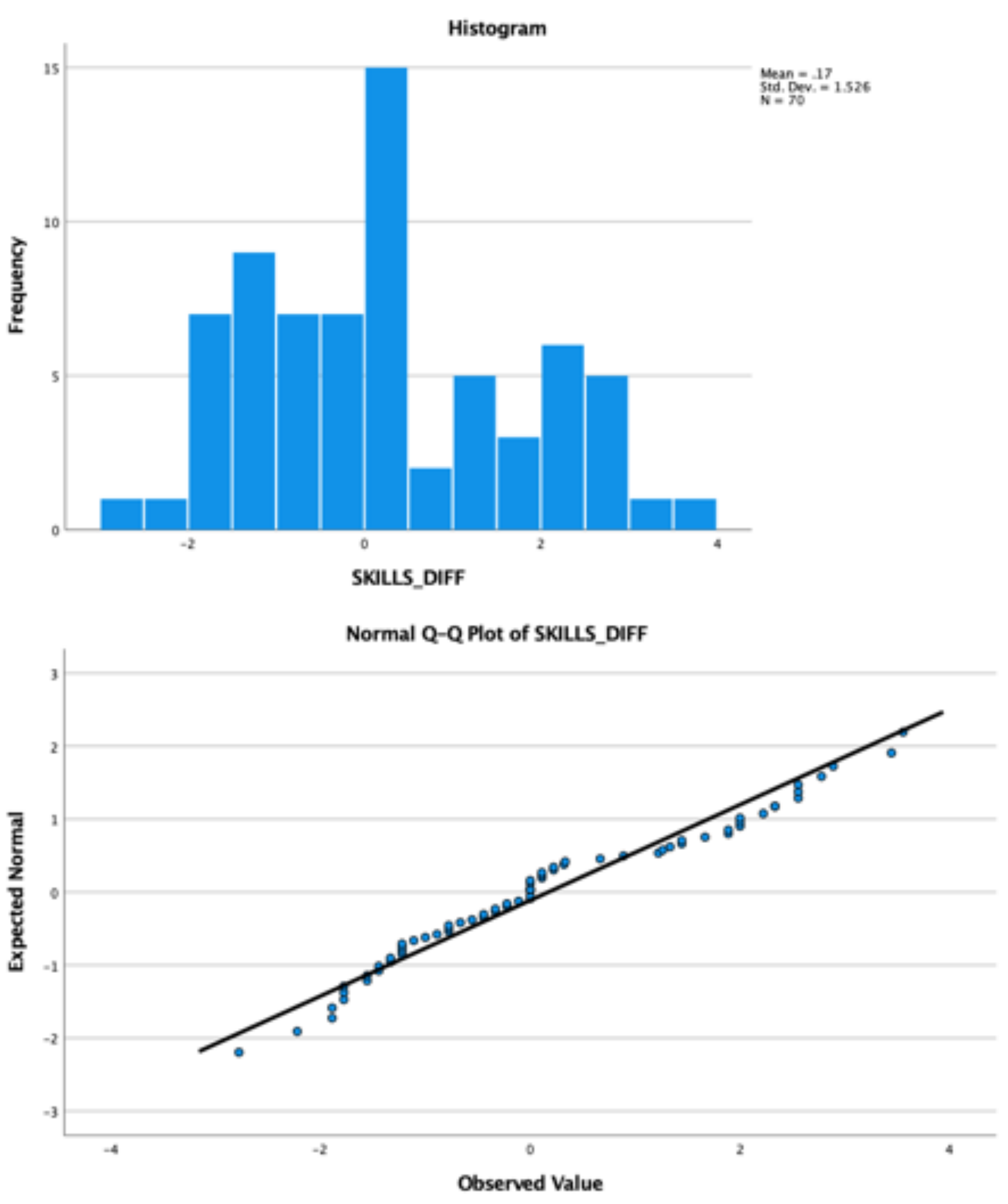


Figure 88: Histogram and QQ plot for pre/post-test gain scores for self-efficacy

A Wilcoxon signed-rank test showed that a one-off training event did not elicit a statistically significant change in self-efficacy in individuals (Z = -.658, p = 0.511, r = -0.08), despite the median Skills Score rating being higher post-treatment (gain = 0.56). Of the 70 participants, 34 participants showed a decrease in self-efficacy whereas 32 participants showed an increase in perceived self-efficacy to task completion. For 4 participants the intervention did not affect their perceived levels of self-efficacy. The effect size is small indicating that the training intervention did not change respondents' perceived levels of self-efficacy much.

B. Pre/post-test gains of self-efficacy (= SKILLS measure) are higher in Succeeding iterations in the treatment group.

A one-way ANOVA was performed to compare the effect of the training event on perceived levels of self-efficacy.

To test this assumption, I conduct a one-way ANOVA to measure the pre/post-test gains of motivation in succeeding iterations in the treatment group. The eight different iterations of the training activity are used as the independent variable and skills gain scores form the dependent variable. Levene's test was used to assess the homogeneity of variance which is one of the assumptions of group mean comparisons. Levene's test indicated a non-significant result and therefore we can assume equal variances, $F = .425$, p-value = 0.883, and the assumptions for a one-way ANOVA are met. An analysis of variance (ANOVA) revealed significant between-groups differences for amotivation, $F\ (7,62) = 26.826$, $p = <.001$, $d = 0.75$. Indeed, the mean skills gain shows an upward trend in the succeeding iterations (see figure 89).

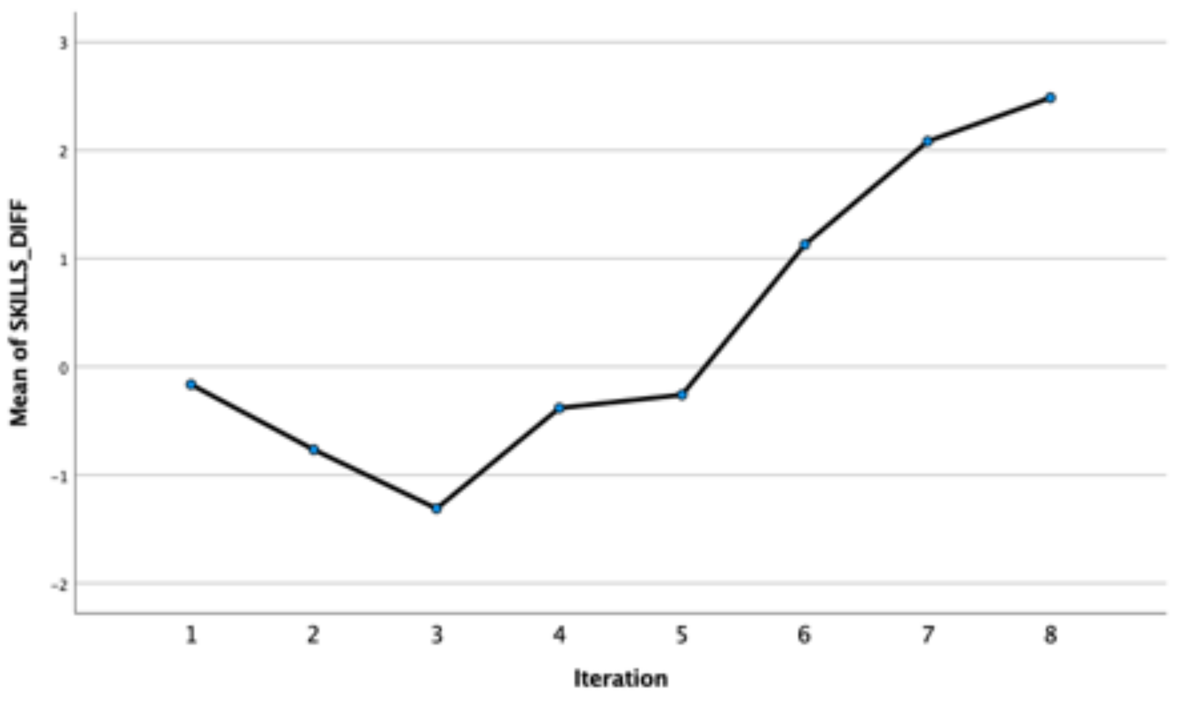


Figure 89: Mean gain scores for self-efficacy across different iterations of the training event

C. Posttest levels of self-efficacy (= SKILLS measure) are higher in the *final treatment group than either control group*.

I compare the post-test scores for *skills for science inquiry* of the treatment group with post-test scores for *skills for science inquiry* in the treatment-as-usual control group and the tricot users control group for the final iteration of the training event. The assumption for normal distribution of the data is not met for the tricot users control group (W = 0.89, p-value = <.001). Levene's test of homogeneity of variances shows a rejection of the null hypothesis (p-value = .028) and suggests the use of a non-parametric equivalent for a one-way ANOVA.

The Welch test shows that there is no statistically significant difference between the three groups (p-value = 0.890) for skills. We cannot conclude that post-test perceived levels of skills for science inquiry are higher in the final treatment group compared to the treatment-as-usual control group or than the tricot users control group.

Impact of iterative design on research literacy

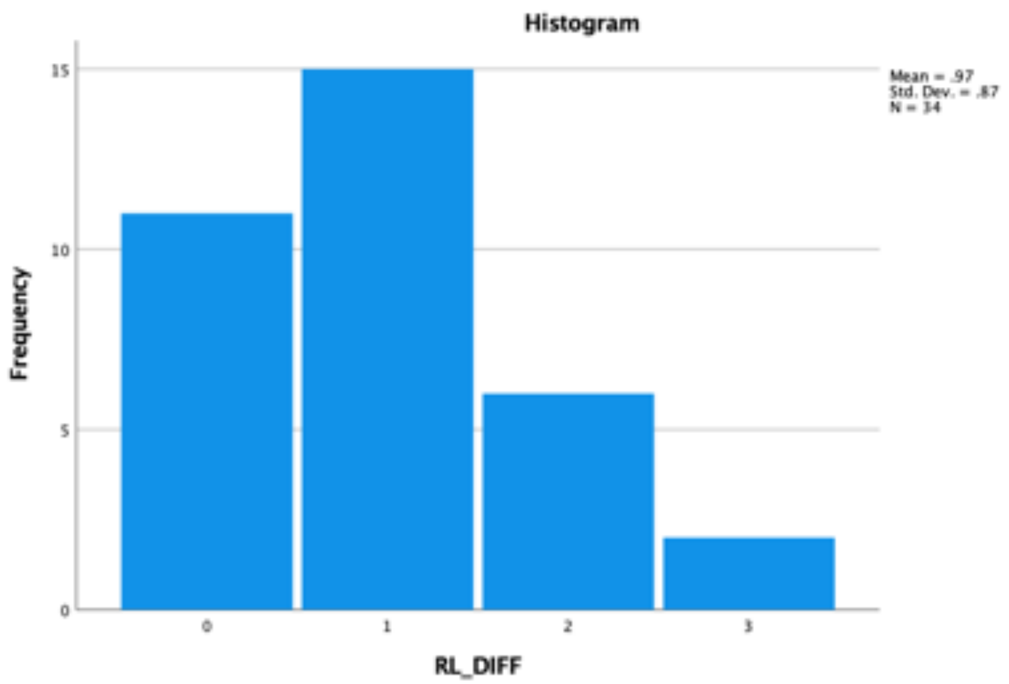
There are pre/post-test gains in research literacy (= qualitative measure of understanding) in the treatment group.

I compare the pre/post-test gains in research literacy. The research literacy measure was developed in subsequent rounds of data collection (iterations 4-8) with a total of 34 respondents. Normality analysis of the pre/post-test scores for research literacy indicated the non-normal distribution of the data. Skewness and Kurtosis are within bounds (see table 18).

Table 18: Descriptive statistics for skills for science inquiry for the treatment group

						Shapiro Wilk		
Measure	**n**	**Mean**	**SD**	**Skewness**	**Kurtosis**	*W*	*df*	*p-value*
Pre-test	34	0.26	0.567	0.403	0.788	0.523	34	<.001
Post-test	34	1.24	0.987	0.403	0.788	0.872	34	<.001

The Shapiro Wilk shows significant results for the pre/post-test gains (W = 0.84, p-value = <.001*)* indicating that the data is not normally distributed.



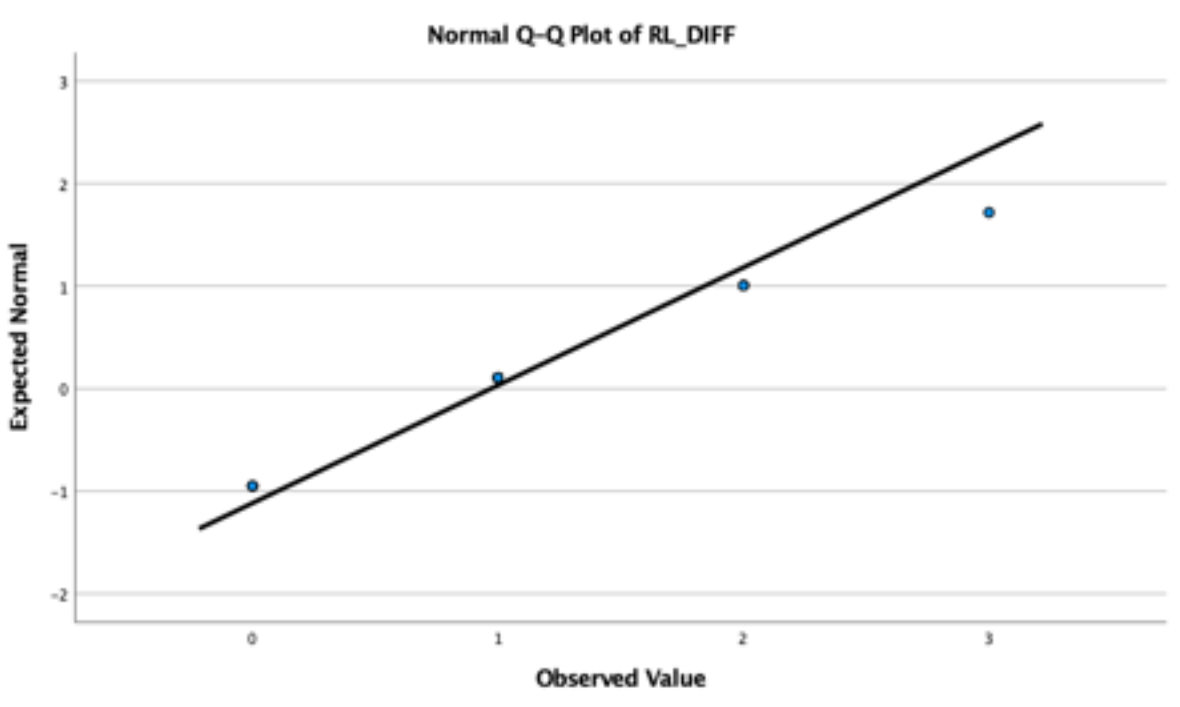


Figure 90: Histogram and QQ plot for pre/post-test gain scores for self-efficacy

A Wilcoxon signed-rank test revealed that *research literacy* scores were significantly higher after the intervention (*Md* = 1.00, n = 34), compared to before (*Md* = .00, n = 34), z = -4.35, p = <0.001, with a large effect size, r = -0.52. Of the 34 participants, 23 participants showed an increase in research literacy and for 11 participants research literacy stayed the same after the training event.

B. Pre/post-test gains of research literacy (= qualitative measure of understanding) are Higher in succeeding iterations in the treatment group.

To test this assumption, I conduct a one-way ANOVA to measure the pre/post-test gains of motivation in succeeding iterations in the treatment group. The eight different iterations of the training activity are used as the independent variable and research literacy gain scores form the dependent variable. Levene's test was used to assess the homogeneity of variance as it is one of the assumptions of group mean comparisons. Levene's test indicated a non-significant result and therefore we can assume equal variances (F = 2.693, p-value = 0.051). Non-normal distribution of the data is assumed (see table 11.7).

The assumption of normal distribution was violated, therefore the Welch F ratio is reported. No significant effects were detected in the analysis $F(4, 12.90) = 2.894$, $p = 0.65$. This might be an indication that the design of the training event has a limited effect on participants' level of understanding of the research process. Games-Howell post hoc tests for the comparisons of different iterations show that there are significant differences (p = 0.039) between iterations 6 and 7 only. Indeed, the mean research literacy gain (figure 91) shows a decrease for iteration 6.

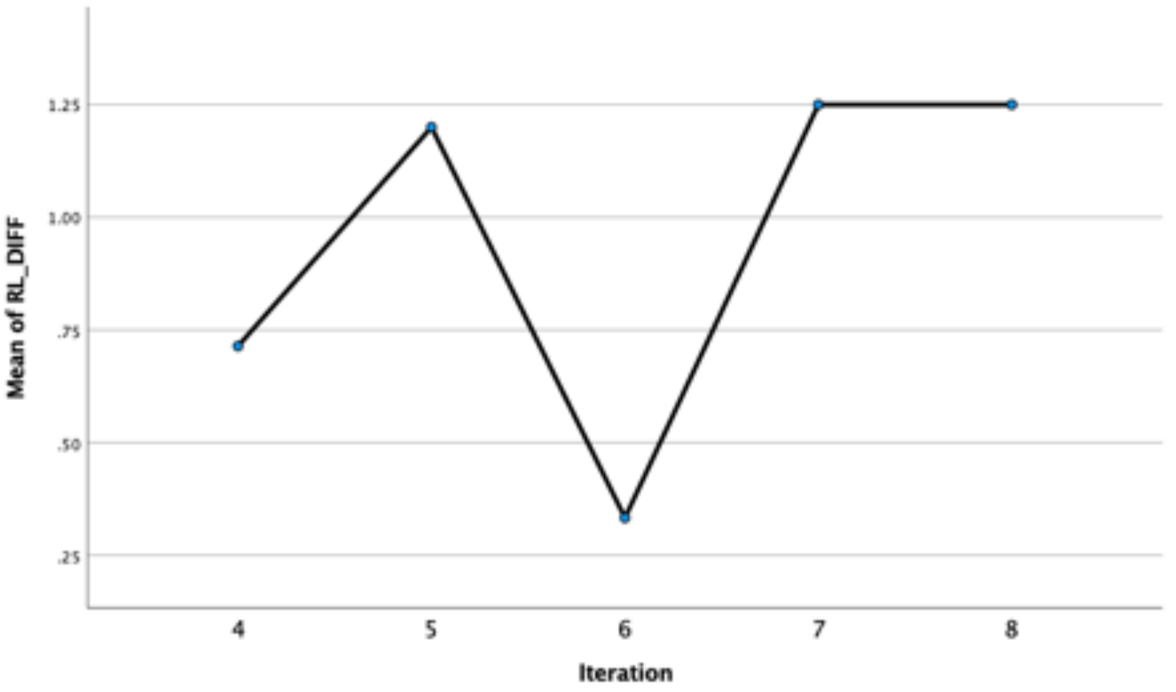


Figure 91: Mean gain scores for research literacy across different iterations of the training event

C. Posttest levels of research literacy (= qualitative measure of understanding) are higher in the final treatment group than either control group.

I compare the post-test scores for *research literacy* of the treatment group with post-test scores of the treatment-as-usual control group for the final iteration of the training event. The assumption for the normal distribution of the data is met (table 11.7). Levene's test of homogeneity of variances confirms the null hypothesis (p-value = .407) and we can assume equal variances.

Table 19: Descriptive statistics for research literacy for science inquiry for the treatment group

						Shapiro Wilk		
Measure	**n**	**Mean**	**SD**	**Skewness**	**Kurtosis**	*W*	*df*	*p-value*
Control group	6	1.33	0.816	0.845	1.741	0.822	6	0.091
Treatment group	8	1.38	1.061	0.752	1.481	0.912	8	0.366

A one-way ANOVA reveals that there is no statistically significant difference between the treatment group and the treatment-as-usual control group in the final iteration with $F(1,12) = .006$, $p = .934$, $r = 0.001$. Perhaps the measure of research literacy is inadequate for testing gains in respondents' levels of understanding, or the differences between the two training interventions for the treatment and the treatment-as-usual failed to show significant differences.

Gains in research literacy

The posttest saw gains in the number of 'scientifically literate' individuals for all three qualitative data points. The effect was strongest for the second question on '***why it is important to compare the performance of different varieties***' with a gain of 42% in the number of individuals providing 'literate' answers. See figure 92. Individuals considered to be 'not literate' are not included in this table. Literate answers indicated that comparisons can help to make decisions on which crops to choose based on their specific context, on the benefits of sharing data with others, and to understand the different effects that pest & diseases, climate, management of crops, might have on the performance of varieties. The gain in the number of individuals for the first question '***what does it mean to do a research experiment'*** was 19% and the gain in the number of individuals for the third question on the importance of setting up experimental plots was 15%. The number of participants considered to be 'not scientifically literate' according to the adapted literacy scales exceeded the literate number of participants with an average of 91% on the pretest and 66% on the posttest.

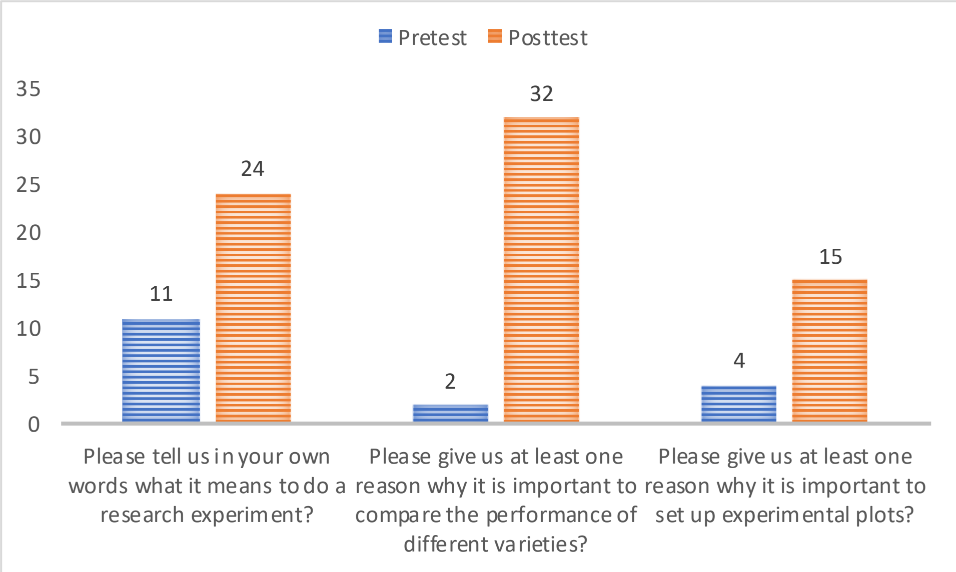


Figure 92: The difference in the number of research literate individuals based on qualitative data (n = 66).

The treatment group shows a higher level of literacy as compared to the control group. The research literacy score was calculated by adding up the number of 'literate' answers provided for the three qualitative questions (see figure 93).

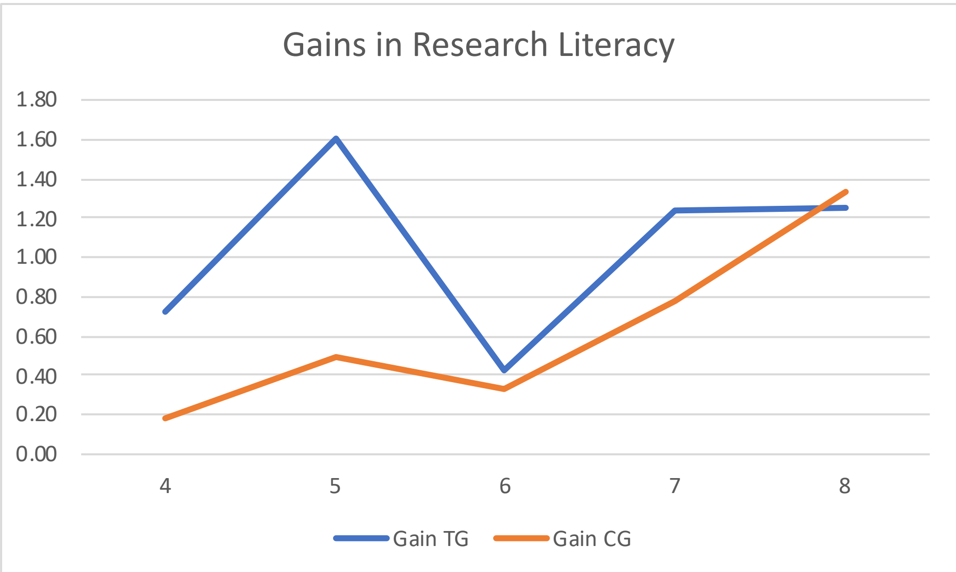


Figure 93: Mean gain scores in research literacy for the treatment (n = 34) and control group (n = 32)

9.3.5 Qualitative data

Probing kits

As part of the experiential kit, feedback on the experiment was promised after the participants would send their data to the researcher using SMS. From the 81 packages distributed, we did not receive a single response.

Farm visits

Twenty-nine visits were made to farmers who received an experiential kit / probing package across different rounds of fieldwork. The visits provided useful information on the level of understanding of the research process as well as their willingness and ability to comply with the research process. As fieldwork took place sequentially certain groups of farmers had more time to plant their trials than other farmers. In cases where the experiential kit was handed out recently, farmers showed their nurseries where they planted their seeds, rather than the kitchen gardens. Not surprisingly, the first round of fieldwork showed a higher average on the extent of usage of the trial package (mean = 5.5) and the lowest average on explaining the different steps in tricot (mean = 2).

The data collection template was hardly used. In round 1 one out of 10 farmers had filled data in the booklet, in rounds two and three 2 out of 11 farmers and 2 out of 8 farmers respectively, had partially filled the booklet or at least taken in its contents and used some of the instructions. Some farmers make notes in their notebooks or keep memories and will fill the booklet later, a few people indicated that they would ask for help to make sense of the booklet, and most people indicated that they will fill the booklet after they transplant the seedlings into their kitchen gardens.

Experiential learning

Respondents described what they intended to learn from the experiments. In terms of direct learning, a majority of the answers indicated that learning about crop specific requirements (in terms of taste, pest, and diseases, germination rates, water use, harvest frequencies) was most important (18% of the answers) followed by how to earn income or save money by growing vegetables (14%). More generic answers about which of the technologies are most suitable for their farms, or which variety offers the most benefits as well as learning about kitchen gardening or growing vegetables ranged from 4-9% of the answers. In terms of learning from other participants or indirect learning less than 10% did not provide an answer to this question, therefore we can conclude that the training activities in both the control and treatment group conveyed the message that by participating in this experiment, the learning effect will go beyond their farms. However, the answers provided by the visited farmers (roughly 25% of the participants) indicate that they expect that this learning will take place outside of formal project communication. Not from feedback on the trials, but from communicating with other groups and farmers in their (nearby) communities: learning and comparing farming practices with others (33% of the answers), learning about new technologies or crops that they were unable to experiment with (28%) and sharing knowledge or seeds and training others within the community (14%). Comparing results with others as a form of competition (7%), sharing market information and prices (<5%), and working together as a group (<5%) made up the remainder of the answers.

9.4 Discussion

A pre/post-test survey was used to measure the motivation, self-efficacy, and level of understanding of the research process (research literacy) before and after a training event (=intervention). Analysis of the data showed gains in research literacy, amotivation (reversed), and self-efficacy after the intervention. Positive correlations were found between research literacy and self-efficacy. Noticeable differences between iterations of the intervention revealed non-linear variations in gains in amotivation, self-efficacy, and research literacy.

The linkages between research literacy and motivation or self-efficacy

Research literacy was positively correlated with self-efficacy and this suggests that the training event was successful in increasing participant understanding of scientific practice and research purpose and that this positively contributes to participants' belief in their ability to successfully complete a research activity. It flags the importance of providing (future) participants of citizen science research with sufficient knowledge and understanding of the research process beforehand. Especially if we take into consideration that rewards and incentives will not necessarily lead participants to take action unless they have a firm belief that they also have the ability to perform the tasks that are required to obtain these benefits (Bandura, 1997).

A lack of a statistically significant correlation between research literacy and amotivation indicates that an increased understanding of the research processes might lead to more confidence in the ability to successfully carry out research, however, this doesn't necessarily lead to increased motivation. Self-efficacy can be developed or enhanced, however as Bandura (1997) indicates this consists of more than a belief in one's abilities and is influenced by external factors, for example, through social comparison, experiences, and affective and physiological states (e.g. Mood). Self-efficacy on its own cannot fully predict changes in motivation.

Does iterative design impact the effectiveness of training activities?

The iterative testing of training activities provided data on two levels. First, in terms of the quantitative data on levels of research literacy, I found that pre/posttest gains in self-efficacy are higher in succeeding iterations for the treatment group. This suggests that as the training was being developed further, participants felt more confident that they were able to fulfill the tasks and successfully carry out a research trial. Whilst research literacy and amotivation show respectively large and moderate effects on pre/posttest gains, there was only a marginal upward trend visible in succeeding iterations. The empirical research presented in this chapter has been the result of a design process of iteratively testing different training methodologies in low literacy environments. Design processes are per definition not linear, and the results show a non-linear reception of the different iterations over time. Each iteration took place in a different location and with varying training activities. The starting values of each group differ in terms of prior research exposure, education, or contextual differences. From our data, we can conclude that amotivation in our population was low to start with, and became lower after participants received more information on tricot. Providing more information on the task leads to an increase in interest in participating in tricot.

However, amotivation has lower values in the second and the fifth iterations. This could be explained due to the content of the training events. In this particular iteration we tried new co-design activities. Co-design methods might be more engaging but fail to deliver better outcomes in terms of research understanding. However, when we compare the treatment and the control groups for these iterations we see similar results for both groups. External effects are likely to have impacted these results. The data clearly illustrates the effect of group dynamics and context on the outcomes of an iterative design process involving participants. Setting up a design process involving different groups will increase the reliability of the outcomes of the design processes.

Limitations

I chose to conduct the design experiment with two treatment groups. The treatment group subjected to the iterative design of training activities and a treatment-as-usual control group. The data indicates that is an upward trend in the reception of the treatment-as-usual control group from the first to the last iteration, suggesting that the facilitator of the training as usual also improved her activities over time. I had hoped to see a larger effect in the treatment groups as compared to the treatment-as-usual groups. I chose to randomly assign each respondent to a group and keep the activities constant in timing and location, to avoid introducing additional bias. However, the training activities were designed using a process of explorative design research and generative activities. For future research, it might be worthwhile to include a few anchor points into the designs that can serve as means of comparisons between the different iterations.

This study explored whether research literacy positively correlated with motivation and self-efficacy for participants of a citizen science-inspired agricultural research. Whilst every care was taken not to alter the scales, in practice biases might (and probably have) contributed to lower internal consistencies than reported in the literature (Guay *et al.*, 2000; Standage *et al.*, 2003). The 16 items that comprise the SIMS measure (Guay *et al.*, 2000) and the 23 items derived from the DEVISE measure (Phillips *et al.*, 2015) were translated into the local language kikamba without cross-cultural verification of the appropriate terminology. Furthermore, the items were translated on the spot rather than having a translated document which might have impaired the consistency of how questions were posed.

A second issue that must be considered when interpreting the results, is that the Situational Motivation Scale has mostly been validated in studies covering academic, leisure or sport, and interpersonal relations life contexts mostly for college students (Standage *et al.*, 2003;

Martín-Albo, Núñez and Navarro, 2009). Implementation of the instrument in a rural setting with a low literacy for scientific endeavor in addition to inarticulacy in the English language probably affected internal consistencies and construct validity. The DEVISE measure which has been designed for measuring outcomes and evaluating situated Citizen Science projects across a range of different life contexts, and therefore might have been able to generate more robust results. However, due to its niche application, this scale has not attained the same levels of verification and validation as the SIMS scale. This is one of the reasons why I chose to develop a combination including both scales. I did not validate the design of the measurement before its use and therefore, as reported in the results, we should be cautious with interpreting the results.

The distribution of the cultural probe which serves in practical sense as an instruction booklet and workbook for the tricot trials, did not generate any feedback from the participants. Much attention was given to the probe in the training sessions, especially considering it could double as a handy training tool, and participants were interested in receiving it. This was demonstrated by requests for additional booklets from villages where we were unable to provide them to all participants. Perhaps it was unclear how the cultural probe should be returned, and participants were waiting for us to pick it up. However, farm visits showed that whilst the farmers had eagerly taken the contents of the cultural probe and planted the seeds, the booklet as such was not consulted. Some indicated that they were waiting 'for further instructions' whilst others shrugged and diverted the conversation back to the nursery or the field where the seeds were growing. Whilst farmers undoubtedly have much experimental data to share, which was repeatedly demonstrated during the farm visits, they did not see much use in writing it down.

Chapter 10
Discussion

10.1 Introduction

This thesis contributes a range of knowledge on the application of design approaches and design research, which are expected to be valuable to both agricultural researchers and for designers concerned with the design of participatory processes in low-income countries. The aim of this research was to explore how designerly approaches and participatory design tools can support the design of more engaging user interactions in agricultural research. The study has yielded a great deal of experience in co-designing with rural communities. Further insights have been gained into the value of using a design process and design research to explore participation and engagement of farmers into research processes. This chapter discusses these observations and experiences, categorised in three broad sections: new ways of motivating participation, the application of participatory design in agricultural research, in particular in the fuzzy front end of the design process and moving the discourse of design and design thinking in agricultural research beyond user-centred design.

10.2 Large scale implementation of participatory agricultural research requires new ways of motivating participation

Participants have multiple and diverse motivations to participate in agricultural trials, including learning, social interaction and complying with expectations from field agents (Trumbull *et al.*, 2000; Brossard, Lewenstein and Bonney, 2005; Bell *et al.*, 2009; Jordan *et al.*, 2011; Riesch and Potter, 2014). In this thesis, we looked at a citizen-science inspired example of participatory agricultural research and went through a design process to explore how we could use design to increase engagement or motivation. Previous research on motivations in tricot trials by Beza *et al.* (2017) showed that there is a group of tricot participants driven by intrinsic motivations (learning, contributing to scientific research and sharing information) and a group driven by extrinsic motivations (expectations, interactions with researchers and with the community). I did not find such a strong division between intrinsic and extrinsic motivation. By studying the motivations of recent participants in a tricot research experiment, I found that a strong incentive to start participation is the evaluation of crop varieties on participants' own farms. However, what motivates participants to sustain their participation is the ability to work in groups and compare their results with others or having a general interest in participating in research. This indicates that what drives people to start participating and gets them on board, is not what will keep them motivated to participate over time. This might have implications for the design of the research approach. Taking into account the motivations of farmers could help to predict attendance and level of participation during different research stages. The amount of time and effort farmers are able to dedicate to research trials is limited and farmers strategise on which stages will provide the most benefits to them. This suggests that the design of participatory research should allow for different groups of participants to take on different roles and participate with different intensity throughout the research cycle (Hauser *et al.*, 2016; West and Pateman, 2016; Beza *et al.*, 2017). Similarly, researchers often choose different forms of participation for different research phases and 'jump between types of participation' (Johnson *et al.*, 2000; Giessen and Nichterlein, 2005). As such it would be difficult for any definition of participation in a research project to be a predetermined or static concept. This makes it arguable much more difficult to design for.

10.3 There is a need to involve users into the design of research

Normal incentives that drive participation in agricultural research might not apply when we move from small scale to large scale implementation of participatory agricultural research. In the literature review it was suggested that recent advances in citizen science might open new avenues for participatory research in agriculture. This is because citizen science' ideology of democratizing science through involvement of the public, has led to more efficient and effective ways of knowledge generation whilst at the same time offering educational value to its participants (Shirk *et al.*, 2012; Bonney *et al.*, 2016). Whilst citizen science offers many areas of convergence with participatory agricultural research, there are important lessons to be learned both in terms of participant motivation and how to involve the user into research as well as in terms of implications for designing participatory research.

In agricultural research it is widely acknowledged that participation of farmers and other stakeholders increases the efficiency of the research process and the validity of its outcomes. Without proper farmer consultation and inclusion of their personal goals and their preferences, participatory agricultural research can at best be considered: "researcher-managed and farmer-implemented" (Ashby, 1986:p.6). In this early article, the author demonstrates that participation of farmers is more efficient compared to using diagnostic surveys to determine the design of agricultural trials (Ashby, 1986). Consulting farmers before researchers have determined what technology to test and how to carry out the trials, produces significant changes in the design of the trials guided by insights on how farmers would evaluate the trials and how to structure the research. The paper concludes that farmer participation in experimental design for on-farm trials requires fewer resources and less time than diagnostic survey research while at the same time qualitatively improving feedback between scientists and farmers. However, to this date I have only found a handful of examples in the literature on including users in the fuzzy front end where design decisions are made. Most of these examples stem from farming systems research, innovation networks and digitally supported agricultural interventions (see for example (Meynard, Benoit Dedieu and Bos, 2012; Schut, Klerkx, *et al.*, 2016; mccampbell, Schumann and Klerkx, 2021). Involving users into the early stages of the research process where design decisions are made, ensures that participants' goals and experiences are included and might help to reduce 'design-reality gaps' (Vaidya *et al.*, 2011).

In participatory agricultural research, the design of participatory processes is often opportunistic. Whilst agricultural researchers and their institutions hold important knowledge about the needs of farming communities as is evidenced by their literature, impact assessments and research experience, this is often not explicitly brought forward in the design phase of agricultural research. Scientists with extensive field experience would be a great source of information during the initial design process which normally takes place anywhere between the identification of a research need and the start of implementation. Design decisions are proposed in grant proposals and formalised during the contracting phase. Experiences, knowledge, interests and resources of end-users might be included in the design implicitly, however, this assumes that scientists are somehow able to 'naturally' shift their perspective to that of the participant and have a clear understanding of the user experience. Interviews, group discussions and surveys are common tools in agricultural research to solicit inputs from users to inform the design of trials or determining research priorities (Hall and Nahdy, 1999). However, design ideas do not only emerge from piecing together user needs and research requirements and placing all this information in context.

Standard practice in the design of participatory agriculture depicts a linear or circular research model of identifying the problem, design of a proposed solution or hypothesis, implementation, monitoring and evaluation. Often the solutions to the problem are proposed in the grant proposal stage before funding has been acquired. This makes it difficult to alter the problem definition at a later stage and divert far from the initially proposed solutions. Similarly, most of the research in agriculture is made up of a deductive or inductive approach. Design research differs from deductive or inductive approaches through its more open and exploratory approach to study phenomena. Where deductive approaches test an existing framework or hypothesis, and inductive approaches aim to identify themes with the aim to build theories, an abductive approach aim to find out what might be possible without narrowing it down to a single solution. Abductive research processes combine the inductive approach of generalising existing ideas and the deductive approach of narrowing down existing choices to develop a new understanding of a phenomenon. This then can be used to provide future directions and suggest potential design solutions. This might seem a bit vague. Design frameworks like the double diamond which I used in my research process, can provide a useful scaffold for this intentionally undefined process. Following a design approach could potentially change the way we conduct our research by allowing more time for reflection throughout the different phases, documenting how design choices are made, making room for exploration first before determining the problem and finding solutions and creating more space for 'trying things out' before narrowing down to potential solutions.

10.3 Participatory design for agricultural research

Participatory design explores ways in which design can be used to understand the experiences and behaviour people have when interacting with a product or a service. It uses tools and techniques specifically designed to explore what it is that people do or feel, rather than what they say they do (Chamberlain *et al.*, 2012). This is of particular interest in my research as participatory design offers direction for involving users in design processes. Much like participatory research, design literature indicates the importance of embedding the values of the user into the design process as an important prerequisite to create relevant products and services. In product design this is often referred to as the "fuzzy front end" of development when designer teams go through a process of discovering 'what to make, who to make it for, understanding why to make it and what it would take to make it successful'

(Rhea, 2003, p145). The fuzzy front end brings together primary and secondary data from a variety of sources. The concept refers to the pre-design phase where the problem space is not yet clearly defined and deliverables can still take any form or shape (Sanders and Stappers, 2008; Sleeswijk Visser, 2009). In this phase, designers gain an understanding of the users, the user context and explore the technical opportunities of the design solutions (Sanders and Stappers, 2009). The fuzzy front end starts when the need for a product or a service arises until the 'formal' design process starts. This is where including a user perspective adds most value, however it is also the phase which often gets underfunded as managers prefer to see tangible results or designs rather than a carefully constructed thought process (Smith and Reinertsen, 1992; Sumberg *et al*., 2013).

In the research for this thesis, user interviews provided insights into the perceived experiences of tricot participants. User interviews at the beginning of a design process enhanced the understanding of the user and the user context and I was able to generate rich information on their motivations and expectations. This rich information source became an important input in my exploration of the user experience in tricot research. My involvement in developing the tricot approach and years of working with farmers in our user context prior to commencing this research, gave me *some* knowledge on the realities in which participants set up trials and monitor their progress as well as some of the hurdles to participation in tricot trials. However, I had never shifted my perspective in such a way before, and this helped to reframe the original problem statement.

Participatory research, therefore, requires initial investment in research design, recruitment and needs assessments. Participants in agricultural research require information and support on the activity they are asked to perform to be able to decide whether participation is worthwhile. They also need to understand the outcomes and other direct benefits to further incentivise their participation. This onboarding process usually concludes the final phase in the design of participatory research when researchers and implementers 'go to the field' to establish rapport with the user group and start the research process. However, this often becomes a researcher-led approach without providing participants much opportunities to negotiate the goals and structure of the research process. Involving farmers into the design of data collection and feedback delivery formats might increase mutual understanding and lead to improved data quality as well as determining what valuable learning outcomes could be for participants.

Whilst the first design experiment showed that aesthetics and better designed formats might help to improve participant motivation, it can only partially solve the issue of engagement. I used a second design experiment intended to measure levels of situational motivation before and after a tricot training event, to establish if there is a correlation between an individual's level of research literacy (their understanding of the research) and motivation. I did not find such a correlation, nor did I find significant changes in levels of intrinsic motivation, identified regulation and external regulation before and after an intervention. Levels of amotivation showed a decrease after the intervention, indicating more interest in the research approach after the training. This is in line with the general understanding of motivation. Similarly, delivering more extensive training during the onboarding process and training participants on basic trial skills, will improve their self-efficacy and decrease their amotivation. This will likely lead to increased engagement overall, however, it does not say much about the individual level of engagement.

I found that several elements were missing in the research design of our case study: first, there were no clearly formulated learning goals (that make sense to the end-user) other than 'finding out the results of the trials'. It would be better to translate the learning goals into tangible outcomes on the side of the participant and then design exercises or activities around these. Second, accountability towards the participant in terms of information delivery and feedback on the results of the trials was not extended from the researcher to the implementing organization. Perhaps the goals of the research were not sufficiently expressed by researchers who just assumed that it would happen if they ask for it, and not much efforts were put in the design of feedback materials in such a way that it would be sought after or valued sufficiently by the participant. Too often researchers have the ability to get people really excited about the potential outcomes of the research but it stands or falls with empowered implementers. If there is nobody around to carry this forward, it might result in a less-than-optimal or partial implementation of the ideas at the time of designing the research. Perhaps, a useful design venture could be to apply a middle-out design approach to investigate the role of the implementors and see what gains could be made to address existing challenges. This would require a in depth look into all the different facets involved in delivering a service, including the user and the service providers' experiences by designing for all touchpoints where stakeholders interact (Dow, Comber and Vines, 2019). Rather than seeing them as an inevitable part of conducting research (the need to outsource the practical implementation of the research, especially when implemented at scale), a middle out design ensures that the needs and knowledge of the implementers (those who seem to be stuck in the middle) are taken into consideration and they have the means and the incentives to do the best they can.

When researchers involve users into their research processes, they often work through implementing organisations who have a network in the research area. When farmers work with these organisations, there is a certain level of reciprocity which makes them more willing to agree to participation even when the direct benefits are unsatisfactory. This is different from citizen science which mostly relies on volunteer contributions. Participants in tricot research might not have the same access to information and knowledge as can be assumed from a citizen science participant in middle- and high-income countries. Agronomic knowledge is notoriously hard to obtain for rural farmers in our context. This makes participants more willing to undergo tedious processes of extractive data collection as it might bring information they would otherwise not have access to. Contrast this with citizen science bird tracking. Volunteers gain knowledge from the process in a *form* they otherwise wouldn't have access to. For example, access to knowledge made easy or brought to participants in a playful way. Or they do not need to do research themselves but are able to learn by simply participating. However, the factual knowledge would probably be available to them even if they chose not to participate. This is different from the realities of rural farmers who might also be able to access detailed information on crop performance if they went out of their ways, but the 'going out of their way' part is much more constrained due to limited access to internet, a lack of digital literacy or scientific literacy, and the availability of such information, especially if we take into account that most agricultural research focuses on major commodity crops and tends to neglect so-called underutilised local species (Padulosi, *et al.*, 2013).

However, a more important oversight might be the assumption that farmers willing to participate in agricultural research would have the same levels of scientific literacy as is assumed for citizen science projects. Scientific literacy is an important precondition for engaged participation. This is in line with previous studies in citizen science, however this is a new concept for the field of participatory agricultural research. The difference in citizen science is that it aims is to increase scientific literacy through participation. Scientific literacy is seen as an outcome, not a prerequisite for participation. This changes the narrative and implies that the research should be designed in such a way that one of its main features is not data collection but facilitating learning opportunities for participants. I did not find any literature on the concept of scientific literacy in participatory agricultural research, therefore the insights generated in this dissertation will contribute to starting a discussion on this topic.

The research in this thesis shows that there might be a lack of communication throughout the different phases of the tricot research cycle with much emphasis on onboarding the participant, and little communication after the data has been collected. Insufficient training of participants in data collection and basic research skills and a lack of feedback after trial completion, hinted towards accountability issues and this might have an impact on the level of engagement on the side of the participant. Having a clear value proposition to communicate to participants, setting learning outcomes, and consistency in communication are important factors that influence participants' engagement. The first design experiment, therefore, aimed to test different methods for consistent information and feedback delivery to be able to deliver on the expectations and motivations of participants. Here, we learned that expectations driving motivations are not fully aligned with what the researchers designed the approach for. Without understanding the requirements of the research activities fully, participants are unlikely to be motivated to complete the tasks that are not necessary for trial completion as these are seen as additional activities or sometimes are simply not understood. This is in line with previous studies on citizen science. Evans *et al.* (2005) found that project goals are not understood by nearly half of the participants nor did they understand what the scientists were using the data for. Several authors attempted to measure increases in scientific literacy as a result of participating in citizen science project, but failed to find significant differences (Trumbull, 2000; Brossard *et al.*, 2005), indicating that public participation in research on its own will not increase scientific capacity. This research showed that whilst farmers in east Kenya tend to have high levels of graphic literacy, the value attributed to the data it represents, is low as participants prefer information delivered orally or in the form of a narrative, rather than numbers on paper. A rather abstract representation of data based on scientific principles without making this directly relevant for their farming practices, did not offer enough incentive to sustain participation in the research process. We should not make the assumption that involving farmers into research process will ensure that participants pick up basic or project-specific research skills, have the ability to connect with likeminded farmers or lead to empowerment if the research process has not specifically designed outcomes for this. This requires a more intentional design process, first by understanding the user experience more fully and pre-empting the research outcomes on the side of the participants. Taking this into account in the design of the research process, will enhance the ability of participants to fully benefit from the scientific knowledge it generates. More emphasis on training participants in the research aspects of the approach and designing worthwhile learning outcomes that match participants' interest, could help to improve participant motivation to fully participate.

There seems to be tension in how to design participation in tricot research. Is the tricot approach attempting to teach farmers how to do research by teaching them the basics of setting up experimental plots? Or is it an attempt to design approaches that allow participants in tricot research to do this intuitively or as close to their 'normal' experimentation as possible? The tricot manual (van Etten *et al*., 2020) provides three key messages: first, that carrying out an on-farm trials should be simple without needing any special skills. Second, that any farmer should be able to participate. And third, farmers are farming experts and as such deserve full respect as generators of new knowledge. Indeed, tricot trials are easy to set up and to maintain. Monitoring the trials using a simple data collection sheet is something participants should be able to do or can learn quickly. However, it might not be suitable for every participant. Where I see tension in this approach is where citizen science necessitates providing feedback to participants and in sharing the data. Here, the attempts to provide feedback are not sufficiently developed yet and this hinders the dissemination of research results. Should we teach farmers how to read or analyse the data and deliver it to them on a piece of paper? Or leave it to extension workers to relay the information from the trials? A common approach to both citizen science and participatory agricultural research is to empower its participants by teaching them basic research skills, however this might impose a 'Western scientific mode of inquiry over local innovators procedures' (Saad, 2002: p.4). Farmers may decide to accept the new knowledge and adopt parts of it to use in their own experimentation, or they might decide to play along without internalising them. The research in this thesis confirms this bias as farmers seem eager to carry out the trials under their own management yet seem far less eager to collect data and internalise feedback based on scientific principles. It might be because they lack the scientific literacy to do so, but there could also be an issue in the design of this type of research. If we could find alternative ways of 'collecting the data' from farmers experimenting with different crop varieties which mimics their intuitive knowledge gathering and sharing and designing a worthwhile 'experience' for this, then it might be much more likely that the research process can be caried out as if it were citizen science, meaning that both researchers and participants would benefit fully.

This discussion is not new. To answer the question of whether scientific literacy is a prerequisite for participation in agricultural research, it might be interesting to touch upon a much older discourse around farmer experimentation. Farmers are experts in experimentation, in fact this is what led us to domesticate and grow so many different varieties of crops. Farmers test new varieties or new farming practices and obtain new materials through experimentation. Most of it without any interference of formal research or extension. Nadine Saad (Saad, 2002) wrote an excellent review on farmer experimentation twenty years ago. Differences in understanding of what farmer experimentation and the associated knowledge entails, have led to different approaches to participatory agricultural research. For example, those who view indigenous knowledge and practices as an enormous untapped resource which can be removed from its context and replicated in different areas, similar to scientific research. On the other side there are those who understand indigenous knowledge as something empirically grounded, experiences which cannot be easily separated from its context. Here the emphasis lies on the process in which the indigenous knowledge is created, and how it can be tapped into in parallel with formal agricultural research. This seems to be a fundamental challenge in participation that citizen science does not necessarily address. Further research in 'democratising participatory agricultural research versus more extractive forms of citizen science, might help to clarify how citizen science features can contribute to the design of participatory research in agriculture.

10.4 User-centered design goes beyond usability

Whilst the concept of *usability* focuses on ease of use or effectiveness, user experience implies that enjoyment or aesthetic appeal are of equal importance (Sutcliffe, 2010). Further research into the notion of user experience borrowing concepts and methods from the field of Human-Computer Interaction might offer valuable insights into the importance of aesthetics in design to facilitate beneficial or intended user interactions. A theory of emotion in design shows that in addition to designing for functionality and user needs, taking into consideration the emotional responses users will have when interacting with a product or services will determine its success and acceptance. This research shows that moving the design of participatory agricultural research further than simple questions of usability, user-friendly formats and 'user-centred design' could be a key to a more successful way of motivating participation and open up new avenues for attracting, engaging and retaining participants in our research. This requires additional expertise in design that goes beyond the current knowledge within agricultural institutions. This goes further than adopting a user-centered design approach in the design of agricultural research or services. For example, if you decide to hire an app developer to take care of the design process, you will end up with a working infrastructure that delivers a mobile service. It probably won't look like anything farmers are familiar with and it likely will not function in a way that is acceptable for either researchers and the end users. It is as if we were to ask a plumber (here: the app developer) to design a house, rather than spending the money on hiring an architect first (here: the designer). However, an architect can't work without a structural engineer (here: the scientist) to advise them on the contextual requirements of the build, or even an interior designer (here: the interaction designer) to advise them on the aesthetics and functionality of their ideas. Perhaps what I am trying to convey here, is that rather than asking a researcher to focus on user-centered design, it would be better to attract and build up design expertise on an institutional level. This will prevent introducing a form of design 'light', where the focus lies on involving users through co-creation workshops in strategic phases in the research process, most likely the data collection or evaluation phases. User-centeredness doesn't necessarily need actual user-involvement. Kimbell (2011a) argues that a shallow interpretation of design thinking leads to several issues. First, it might lead to false claims of user-centeredness when designers are still the main agent in the design process. Second, the simplified visual representations of a design process seem to indicate a "unified design thinking" disregarding the diversity of design practices in different institutions and professional fields. This process of design thinking tends to imply that if you follow these steps you will "do" design properly and generate solutions. Third, frameworks often portray a distinction between stages of "thinking" and "doing" ignoring the ability of experienced designers to combine thinking and doing in situated practice.

It seems far more useful to adopt a design methodology than doing design 'light'. The way I see the application of Design Methodology in agricultural research, is by emphasising the process. There seems to be a gap in knowledge in agricultural research institutions in the application of user-centered approaches. In practice too often products and services are developed in the lab, with a focus on adaptive research as a last phase in the design process of products or services. We only tend to go to the field to validate or tweak the proposed solution. Or we end up spending a lot of resources on technology adoption, in other words persuading the farmer to use your technologies or services. In this research, my aim was to argue that the user experience should be the first consideration. For example, if I build this 'thing' then what will it look like if I design it solely for the purpose of the actual user? That would indicate that co-design or user involvement should move further than inclusion into the design or the research process but puts the responsibility on the designer to create systems that *afford* things.

Iterative design allows for the quick testing of many different ideas, even the weird ones, as opposed to investing in a single idea. Prototyping multiple (many) solutions provides a benefit of learning from failure early on in the design process. As part of my Research through Design approach, the main aim of the iterative design was not to increase the fidelity of the working prototypes but to explore different aspects of the artifact, and how well this was received by users. This creates tension in data collection by adding many additional variables and requires a thorough process of collecting observational data. This should not lead to an attempt to document every change and every decision in an attempt to account for this variability. When prototyping possible solutions we are not trying to uncover a 'right' way of designing activities to increase research literacy, we are using the prototypes as artifacts to discover potential issues, to answer any questions we might have on how to design our prototypes, and to learn more about our design solutions. The collection of fieldnotes, debriefing documents, collections of (ad-hoc) observations from all team members who attended the different sessions, photographs, and the detailed account of the design iterations provided a rich source of information to generate insights for future designs. Designers gain knowledge and build up collections of ‘precedent’ through experience. As such, the ‘extra’ work in the fuzzy front end is not lost, but these experiences can be brought to use in subsequent design processes by making the process of design more explicit and documenting how design decisions are made.

10.4 Limitations

Participatory design in agricultural research might be constrained because certain tools and standard measurements “fall dead in the water”. This research uses participatory design as a treasure trove of methods and tools for involving users into a design process. In doing so, several challenges emerged. First, the assumption was made that common participatory design tools and techniques would be appropriate for most contexts. Further study into the origins of these methods, indicated that they are validated in a very specific context. For example, scenarios were used to introduce the task at hand during co-designing the data collection and feedback formats, however these scenarios were understood as real examples and contested by the participants in various groups. Setting the scene based on hypothetical or abstract representations did not resonate with participants in our context. Similarly, cultural probes which are a common tool used in participatory design, did not generate any feedback.

For example, the scales measuring situational motivation which were used for the research described in chapter 9, were developed and validated with American college students (Guay *et al.,* 2000*)*. Similarly, much of the research on citizen science originates from research in western societies and this might have implications when applied out-of-context in low-income countries. Henrich *et al.* (2010) offers an interesting shift in perspective on how the least representative subsection of the human population, serves as a base for many of the theories that guide psychology, motivation, and behavioural research today. A startling number of journals publish research based on ‘samples drawn entirely from Western, Educated, Industrialised, Rich, and Democratic (WEIRD) societies (Henrich *et al.*, 2010, p.4) with the assumption that there is little variation across human populations. In their article they demonstrate that there is ‘substantial variability in experimental results across populations in terms of visual perception, fairness, cooperation, spatial reasoning, categorization and inferential induction, moral reasoning, reasoning styles, self- concepts and related motivations' (Henrich *et al.*, 2010, p.2). The data of the pre- and post-test measuring motivation and self-efficacy showed low internal validities, despite being a reliable measure validated by a substantial number of studies in different contexts. I used the scale as reported, yet still found low internal validities which indicates that the results should be taken in with caution. As seen in the previous chapter, low internal validity of the scales could be attributed to the effect of translating on the interpretation of the standardised questionnaire. Martín-Albo *et al.* (2009) reports similar issues. Whilst language barriers and incomplete translations could be the determinant for some of the lack of internal validity, here cultural factors might further impair the application of these standardised measures.

A single design case in a relatively new area of participatory agricultural research was chosen for this research, to allow for a hands-on approach to prototyping design solutions. This limits the generalizability of the results. The research did not aim to create design solutions for improving an existing participatory agricultural research approach. It qualifies as exploratory design research and uses the case study to provide a user context for our design process. It was not meant to comprise a whole design process. The suggested improvements were intended to explore the feasibility of involving users into a design process and 'finding out ' if participatory design and designerly approaches can be of value for the design of participatory agricultural research. As such we set up two design experiments consecutively as we learned more about the user experiences in the tricot approach. True to qualitative, design-based research, much of the initial empirical work contributed to problem discovery, suggesting a revision of the thesis direction, which has led to a repeated reframing of the research questions. The outcomes are just that, a series of recommendations and experiences which I share to further the discussion on the value of design methodology in the field of agricultural research. I did not attempt to create design solutions that can be implemented to improve either the tricot research approach or participatory agricultural research in general. Therefore, the question on how to engage users into participatory agricultural research remains partially unanswered.

10.5 Future work

In the research of this thesis presented, I took on the perspective of the agricultural researcher, and I was also the main designer of the methods and part of the design team. If I could do it all over again, I would have set up a series of design workshops involving all stakeholders (scientists, local implementers, farmers and designers) where we would design partial solutions to address some of the typical issues in participatory agricultural research. For example, issues of scale, trust, and misalignment between different stakeholders. These partial design solutions could then be taken out of the design 'lab' and brought into the field to explore its feasibility. In the research for this thesis, I explored design solutions with farmers in 'one room' and designed the solutions with other stakeholders in another room. If I had used 'design workshops' where I brought all stakeholders into the same room to tested out the feasibility of participatory design tool, I would be able to demonstrate if this would support getting people to speak the same language, discuss the challenges in participation and find ways of improving the research process. A more in-depth exploration in the implementation of more or less standard participatory design tools and design methods in rural contexts, could be a useful endeavour for the design community. Furthermore, there are standard scales and measurements which have been insufficiently validated in rural communities in low-income countries.

The primary objective of this thesis was to explore new ways of motivating and involving users into agricultural research processes. The ideal outcome of this study would be a set of guidelines on the use of design methodology to design participatory approaches in agricultural research. I could have come up with a set of best practices for the application of participatory design tools that other researchers could use to set up their own design explorations. This assumes that the inclusion of users' subjective goals and needs into the design process and conducting more rigorous research on the user experience in the front end, would naturally lead to more appropriately designed research and lead to increased participant engagement. What emerged from this research is a key insight that designing for increased motivation by focusing on interaction design will only partially address the existing hurdles to participation. Scientific literacy seems to be an important precondition for 'full' participation into research processes. Participatory agricultural research can learn from citizen science approaches on how to involve users into research processes, by adopting the principles of designing research for the public dissemination of scientific knowledge rather than using it to crowdsource or outsource tasks to its participants. This means changing the narrative from offering the 'right' incentives to participation to redesign the agricultural research process to make participation itself the incentive. For this research needs to design for the inclusion of appropriate learning goals and apply a middle-out design approach to ensure that it not only meets the objectives of researchers and users, but also of those implementing the research. Perhaps it is worthwhile for any future research process to go through a process of service design to create the optimal experience for all stakeholders involved by looking at the front end and the back office strategies (Interaction Design Foundation, 2022).

Chapter 11

Conclusions

11.1 Summary

What role can design play in the development of participatory research? How can the involvement of farmers in agricultural research processes be influenced by means of design techniques or tools? And how can designerly methods and tools be utilised to make participatory research processes more engaging for its participants? In the previous chapters these questions have been addressed through a number of studies, using a variety of methods and design experiments. A double diamond design framework was used to guide the Research through Design process and explore methodologies of design synthesis, ideation, and iteration in a more or less logical order.

As a first step in the design process, I took an in-depth look into the 'status' of participation in agriculture. Does it live up to its promises and how did it evolve to where it is now? I explore new innovations in participatory research for agriculture, in particular citizen science and participatory modelling. The research has also been an exploration of designerly approaches and how they can be applied in participatory agricultural research in low-income countries.

An interview study with recent participants in Tanzania in a 2017 to 2018 tricot research cycle, provided rich information and insights on what drives their motivation to participate and discovered some of the hurdles that prevent them to benefit or fully participate in the research. This study revealed misalignment between user needs and researcher needs in terms of inconsistent dissemination of information, poor usability of user-facing forms, and a gap in understanding the value proposition of tricot. It also revealed that participants were mostly driven by extrinsic motivations and direct benefits and that they were unsatisfied with the amount of information and feedback provision after the trials had ended. Reciprocity or loyalty towards the research organisation or the farmer group in itself was a big factor determining participants' motivation even when they did not see sufficient benefits in the project in itself (see chapter 5).

Together with two interaction design students from the University of York and two field officers involved in tricot implementation in our study area, we debriefed and reframed the problem space. Data from the interview studies, contextual data on farmers in the research area and secondary data from reports on tricot as well as my own experiences in developing the approach and providing training to researchers was used to describe the current state of tricot. For example, how the approach works in our user context in comparison with its intended use, and what the major drivers and hurdles in the participatory approach are (see chapter 6). As a team we looked at different precedent to inform our ideation process. We brainstormed for different design solutions and moreover what the realistic focus of our design process could be and decided on a way forward (see chapter 7).

A lack of understanding of the process and its indirect benefits in terms of research outcomes and learning, makes participants less inclined to fully participate. We saw that people are not really motivated to collect data or obtain the results of the trials. One reason might be that they already received their benefits without making contributions to the research. Or it could be that the barriers to participation are too big, for example as the formats used to collect data might be ambiguous, or there is not enough training or feedback during research participation. This led to a first design 'field' experiment where we evaluated different prototypes for data collection and feedback delivery within our study area (see chapter 8). We worked on the front end and focused on improving the communication towards the end-user to see what gains we could make. We learned that there isn't so much interest in the results of the trials as we might have expected. We found that aesthetics and interaction design can lead to increased engagement or flatten some of the hurdles to participation, however, this can only partly tackle the issue of participation. Participants might fail to see the 'bigger picture' of the trials and its benefits beyond growing the different varieties on their own farms and comparing them with their neighbours. This could be for two reasons. Either they do not understand the process fully. This could be possible as it might not have been explained with the right language or it might not have been explained at all. Or they might not attribute enough value to researcher data. I did not find an answer to this question, however came to a different conclusion or hypothesis: scientific literacy is an important precondition for more engaged participation.

In a second study, therefore, we set out to measure if a more explicit design of the training and information provision before participation, might help to increase participants' scientific literacy and if this in turn can impact levels of motivation. I used a pre/post-test design to measure levels of situational motivation, self-efficacy and research literacy before and after a training event. The training event itself increases in fidelity in each training event. Perhaps rather unsurprisingly more training led to a better understanding and higher levels of perceived self-efficacy, however this did not seem to have a measurable effect on participant motivation. We can conclude that a single training event does not have a large impact on participants' individual levels of motivation, however overall the interest to participate grew. It is important to note that this relates to initial participation, it fell out of the scope of this research to investigate what drives sustained participation. I also looked at the iterative design of the training event and whether this has any impact on levels of research understanding, motivation and self-efficacy. Here I found that self-efficacy was higher in later versions of the training event, however, research literacy and motivation gains tend to fluctuate between the different training groups and do not show an upwards trend. This indicates that group dynamics and external effects have quite some impact on the outcomes of participatory design processes. Setting up processes involving different groups might increase the reliability of these outcomes. This led to the first research question:

11.2 Design for engagement

The first question presented at the start of this thesis was: "How might we design more engaging participatory agricultural research that motivates farmers to participate?". The research explored which features of the design of citizen science experiments increase motivation for participation, and how design tools and techniques can be utilised to design more engaging participatory research allowing users to participate more fully in the research process.

The emergence of citizen science-based approaches in formal agricultural research, have opened up the discourse on democratizing science and indicates a reconstitution of the discourse on the challenges and dilemmas of participatory practice. As highlighted in the literature review the scientific value of participatory research is often questioned as it lacks control, replicability or generalizability. Furthermore, it takes longer in the front end to set up research processes and get participants involved. One of the longstanding discourses surrounding participation has been just how much participation would be enough to avoid an extractive relationship with the farmer, whilst at the same time account for the costs of doing research, especially for research involving large numbers of participants. Citizen science offers an answer to the challenges of scaling participatory research. Here we took a pragmatic approach and examined which features of the design of citizen science experiments increase motivation for participation.

Citizen science has brought more attention to research in participant motivation to discover what makes participants willing to participate and where their interests lie (Geoghegan *et al*., 2016; Frensley *et al*., 2017). This research showed that what drives people to start participating and gets them on board, might not be what will keep them motivated to participate over time. Other incentives besides curiosity and an interest to interact with experts are needed to keep participants engaged. A closer look at the user journey indicated that designing communication touchpoints throughout the research process, might help to keep people interested in participating. Taking on an inclusive approach to designing the research, which involves users in setting research priorities and determining learning goals are all solid recommendations which might increase the user experience. I also stated that whilst a user-centered focus might enhance the user experience, it stands and falls with having the implementing organisation on-board as well. This requires more than taking on a user perspective and indicates for a more holistic service design approach. With the research in this thesis, I showed that using relatively small inputs from users and low-fidelity prototypes generates rich insights which in itself can impact how the research process is designed. Participatory design tools are particular useful to design for participation as it affords the inclusion of users into processes through processes of *making* and also facilitates different stakeholders to communicate or 'speak the same language'.

In previous discourses on participation focus lied on the *purpose* of participatory research and whether its main goal aimed to empower, to build sustainable and lasting impact or to serve as a method for increasing efficiency in research. However, with this research I hope to have shifted this focus on *how* we should involve users into our research. This changes the narrative from how much participation is needed to become successful in participation, to what can we do to design an experience that affords a 'desired state of affairs' with more emphasis on giving form than on solving problems. With this I mean that participation doesn't necessarily need to have a single purpose (collect data, ask for inputs, test the validity of a product) but more a co-innovation approach. Together we will solve these problems. We don't know what exactly they are yet, but here we are all together trying to figure it out, learn by doing and testing to see what works. It becomes more about the process rather than seeing participation as a means to an end.

Whilst it was already clear at the onset of this research that involving users in the design of research leads to better representation and design and ultimately to better results. However, with the design experiments carried out in the context of agricultural research processes in rural communities, it became clear that involving users is not as easy as simply persuading them to participate. It is more likely that any participatory process that wants to involve users into research, needs to consider how to design that research so as to facilitate meaningful interactions. Citizen science offers one perspective on how we can do this, however this might not always be feasible in the context of agricultural research. Design research could help to advance the field of designing for participation.

This might mean that researchers might need to reframe their design journey and devote more resources to the front end of the design process. They already test and validate their tools and methods with end-users however it is usually the last thing they do before setting out to implement the research. Moving it back to the start - before anything is set in stone - will ensure flexibility in implementation and might prevent design-reality gaps.

11.3 Value of designerly approaches

The second research question addressed in this thesis was: "What is the value of using designerly methods in the development of participatory agricultural research?" Throughout the duration of this study, designerly approaches have been explored and used in a variety of settings. The research in this thesis has moved the field forward in terms of understanding the applicability of using designerly approaches in agricultural research. Whilst the effects of implementing 'designerly approaches' are complicated and somewhat inconclusive as they depend on numerous other factors, not in the least because I undertook a rather exploratory approach to this research. Some take-away messages are: (1) Interaction design and designing for usability help and can enhance the experience of users when interacting with data collection formats. It can make the tasks in participation more pleasant. However, this will only partially tackle issues around engagement and participant motivation. (2) What gets people on board is not what sustains their participation. Therefore, setting up training sessions at the beginning of a research approach and only following up after the research (or growth season) has ended is insufficient to keep people involved. (3) It is feasible to involve users into the design process of our research process and it might prove to be a cost-effective way of ensuring that participatory research processes are not only appropriate but also a worthwhile experience for its participants. (4) Participatory design offers valid tools for creating deeper levels of understanding. (5) Designerly approaches can lead to a more inclusive design process with the ability to include multiple perspectives.

By emphasizing the design process in structuring our research processes we could build in more time for reflection and design synthesis which will enable us to iterate and evaluate many different solutions. Iterations are needed because there is no single 'right' way of doing things. There are many possibilities that will lead to a desired end-state. Spending more time in the fuzzy front end will create room for exploration of the problem space. It will lead to more documented design choices, rather than black-boxed solutions. Participatory design or designerly approaches allow us to include tacit knowledge and experiences of multiple stakeholders into our designs. There is more time to determine the audience and to actually design approaches to research that allows participants to participate more intuitively (as opposed to 'teach them' how to participate the way we want them to.

Design frameworks such as the one I used in this research are a scaffold for design and not a recipe for doing this type of design research. Once you become familiar with the building blocks and the underlying processes and build up experience you will most likely move away from any type of framework. The work of an experienced designer relies on intuition and following hunches as much as it relies on 'doing' design synthesis, collecting precedent, going through processes of converging and diverging. This is what Jon Kolko tries to demystify in his essay on the 'exposing magic of design' (Kolko, 2011), however I differ and find that it is a process that cannot completely be explained. This might be somehow comparable to the tacit knowledge agricultural researchers build up by frequently going 'to the field', where they learn about the constraints and opportunities, how to communicate better with farmers and pick up certain mannerisms and use this knowledge when writing their next grant proposal. They might not be able to completely explain how they came to a problem statement.

The original contribution of this thesis suggests that it is time to build up design experience in the field of agricultural research. I see a dual role for a designer in agricultural institutions:

1. A designer/researcher who is experienced in carrying out *Research through Design*. This role to explore participatory design tools and designerly approaches to conducting research processes. For example, the use of prototyping, sketching or generative tools or co-design. This would be of particular interest for the advancement of the concept of participation in agricultural research. Experts in participatory design would be able to coach and guide research designers and facilitate design processes.
2. A designer who works on a more institutional level and advocates for more inclusive design of research, to enhance and build up design knowledge within organisations and to push the boundaries when it comes to traditional forms of conducting or structuring research, to evangelise design by educating researchers and managers on the importance of doing user research. This role would entail more reflective research on inclusive research processes involving stakeholders and on democratising science.

11.4 Reflections

This research represents as much as an exploration into design research as it does the validation of applying it in context. This approach allowed me to explore different avenues and change course during the process. This inevitably leaves several aspects less well worked out. A Research through Design approach underlies the work presented in this dissertation, where designerly ways of *conducting* research are used. The research process is structured and carried out as a 'design process' and using design methods and tools as methods of enquiry. Adopting a case-study approach allows me to reflect on the value of these methods by trying them out. I used the methods to validate them in our context and gain insights on *how* to involve users in the design process.

Research through Design plays a formative role in the generation of knowledge and uses design principles or 'designerly ways of knowing' as part of doing research to gain understanding of complex situations. It refers to a different method of scholarly enquiry by framing and reframing research or iteratively developing prototypes (Stappers and Giaccardi, 2017). Using prototypes as tools for knowledge generation, allowed me to explore and evaluate structurally varied prototypes. This made interactions more visual and make the combination of factors leading to the acceptance of a prototype more visible. The only way to explore user experiences is by grounding it in the actual 'thing' to make it meaningful and relevant in its context. Prototypes (or artefacts) are frequently used as a tool for knowledge generation or provocation, not to select the best solutions. I use prototypes and probes as a research tool. I did not have the intention of creating a product or service as an outcome of this study. Through building, evaluation and reflection on prototypes of possible form design or training components, I gained a greater understanding of its effects and its applicability in a particular context

Taking on a Research through Design approach allowed me to shift my perspective from a solution-oriented approach to one that focuses on problem finding. Together with the double diamond framework it offered an effective methodology for reflection, synthesis, and ideation. In my journey from novice to expert designer I made many mistakes, in particular in my interactions with farmers and other stakeholders. For example, I was hesitant to ask participants to join in my co-design activities and when I didn't get enthusiastic responses on the initial activity, I would quickly shift to lecturing or conveying information, rather than creating a dialogue. I was afraid I would resort to extractive data collection processes myself. The tools and methods I designed might not be fully formed and perhaps not as effective as they could have been if I could redesign them today. However, as artefacts they served their purpose and I learned valuable lessons when using them in my research conducting research. There are no 'right' answers and we can learn from failure (a lot). To a scientist trained in natural sciences this vagueness can feel unpleasant and rather unsatisfactory, yet I can now convincingly advocate for the value of having more room for maneuver when it comes designing research processes. Ensuring we have enough time in the fuzzy front end to explore possibilities, gather data and experiences, trying things out will result in a more open attitude to users and hopefully different ways of involving participants in our research processes.

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Appendices

Appendix 1: Interview guide

Research Project "Democratizing farmer citizen science"
Interviewing Guide

Principal Investigator: Jeske van de Gevel

Introduction and informed consent (5 minutes)
Moderator: Thank you for allowing me to visit your home. We want to ask you for your experiences with the tricot approach / the groundnut trials you completed last month / that was completed in this region last month. Overall, the interview should take no more than 90 minutes of your time.

Before we start, I need to ask you to give me your informed consent to participate in this study and record your interview. For this, we have prepared this information and consent form.
<*Hand consent form to participant.*>

Let me walk you through each of the items on the form. Please feel free to interrupt me to let me know if you need more information.
<*Walk participant through all points of informed consent.*>

Do you have any questions? Participation in this interview is voluntary. You have the right not to participate at all and leave the study at any time. This doesn't have any negative consequences for you. And, of course, you're free to take a break during the interview session.
If you feel certain you have understood everything and want to give your consent to participate, please sign at the end of the document.
<*If participant gives consent, hand pen to tick the box for approval on the form. If they feel comfortable to sign the form show them the space for their signature.*

Thanks! Please make sure to keep a copy for your own reference.
<*Hand copy of consent form.*

If it is okay with you, I will now start the audio recording.
<*If participant gives verbal consent, start recording.*>

Main part (50-60 minutes)
<u>Introduction</u>
To start: How did you hear that this trial was about to happen? Can you just describe the situation?

Was there something that made you consider participating? What? Describe. Why was that important to you?

<*Repeat until no new reasons are named.*>

Was there something that made you consider *not* participating? What? Describe. Why was that important to you?

<*Repeat until no new reasons are named.*>

What did you think about the trial at the time? Why? Was that relevant to your decision whether to participate? How?

What did you feel about the trial at the time? Why? Was that relevant to your decision whether to participate? How?

What did other people think about the trial at the time? Why? Was that relevant to your decision whether to participate? How?

ONLY FOR NON-PARTICIPANTS
When did you decide you did not want to participate? Why? What does it mean for you to not participate in this project? Would you recommend others to participate in the trials or not? Why?

Did they take any information from you even though you indicated that you did not want to participate in the study?

ONLY FOR PARTICIPANTS OF THE TRICOT TRIALS

<u>Introduction workshop</u>
Can you describe the introduction workshop? How did it go, step by step?

Was there anything in the workshop that you found hard to understand or do? What was it? What made it difficult?

<Repeat until no new reasons are named.>

Was there anything in the workshop that motivated you to participate in the study? What was it? Why was that important to you?

<Repeat until no new reasons are named.>

Was there anything in the workshop that made you less motivated? What was it? Why was that important to you?

<Repeat until no new reasons are named.>

<u>Planting trials</u>
Can you explain to me the process of planting your trial? How you planted and how you decided to plant? Why?

Was there anything difficult about that process? What? Why was it difficult?

Was there anything in the planting process that motivated you to continue participating? What was it? Why was that important to you?

<Repeat until no new reasons are named.>

Was there anything in the planting process that motivated you to stop participating? What was it? Why was that important to you?

<Repeat until no new reasons are named.>

<u>Making observations on your trials</u>
Can you describe from what you learned when and how to make observations?

Was there anything difficult or demotivating or missing about those instructions? What? Why was it difficult/demotivating/missing?

So how and when were you supposed to make observations?

Can you describe how you actually made observations in the trials?

<If there is a difference between how they thought they should observe and how they did it> Why did you do it differently than you think you should have?

Was there anything difficult or demotivating about making observations? What? Why was it difficult/demotivating?

Was there anything motivating about making observations? What? Why was it motivating?

<u>Observation card</u>
<Show them the observation card they received as part of the project>

In your own words, can you walk me through this card – what does each element mean, and what are you supposed to do and when?

Where there any elements you felt were not explained well by the field officers? Which ones? What explanation was missing?

If you look through these elements, was there anything that was hard to fill in? What? Why?

≤Repeat until no new elements are called out≥

Was there anything you liked about this card? What? Why?

≤Repeat until no new elements are called out≥

Was there anything that we can leave out in the future? Why?

Was there anything missing that we should add? Why?

Was there anything difficult or demotivating about storing the form? What? Why?

<Lay out three different observation cards on the table for comparison (f.e original observation card, colourful observation card from PRUEBA project, blank format with lot's of possibilities to make notes)>
If you compare your card to these others, is there anything you like about them in comparison? Why?

Is there anything you dislike? Why?

<u>Data collection</u>
How many times did the researchers from NARI visit your farm? How long did each visit last? How did they interact with you?

Was there anything difficult about that process? What? Why was it difficult?

Was there anything that motivated you to continue participating? What was it? Why was that important to you?

<Repeat until no new reasons are named.>

Was there anything that motivated you to stop participating? What was it? Why was that important to you?

<Repeat until no new reasons are named.>

<u>Feedback from trials</u>
Have you received any feedback on the trials?

What information is important for you to have from these trials? Why?

Is there anything you would like to know about the observations others made on their farms? Why?

Why?

<u>Participation</u>
Did you participate as an individual or as a group? Why?

Would you participate again? For the same crop or for a different crop? Why?
Not, what would have to be different to convince you to participate again Why?

What did you gain from participating in this research? Did the research meet your expectations? Why (not)?

Are there any challenges you see for this approach that we haven't talked about yet? Which ones? What makes them challenging?

Is there anything else that made it demotivating or difficult for you to participate that we haven't talked about yet? Explain.

Wrap Up (10 minutes)
To close, is there anything that came to your mind we have not talked about that you would like to mention?
<Give time to answer.>

Thanks. Is there anything you would like to ask about this study? To me or to the researchers from NARI?
<Give time to answer.>

Your input is really valuable for us. We really appreciate your taking the time to and answer all these questions. Thanks *so* much!

Appendix 2: Information sheet for collecting data

<u>Participant Information Sheet for Studies Collecting Personal Data</u>

Background

The University of York, Bioversity International and Lutheran World Relief would like to invite you to take part in the following research project:

Democratizing farmer citizen science: designing a coherent methodology from participatory target setting to large-N experiments to ensure engagement and equity

Before agreeing to take part, please read this information sheet carefully and let us know if anything is unclear or you would like further information.

What is the purpose of the study?
We want to understand what drives or prevents participation in large-scale participatory science projects, particularly "tricot" trials with farmers in Africa. We want to develop innovative methods to explain how tricot trials work.

What will happen to you?
We will ask you to participate in structured interviews and co-creation workshops at your home or in a nearby location. Individual interviews will not take longer than 20 to 30 minutes. Workshops should not take longer than 5 hours. We will record the interviews on audio tape and transcribe them, and ask you to fill in a short questionnaire. We will also take photographs and field notes of the workshops, mainly to record the things we produce together.

What are the possible benefits and risks of taking part?
The information learned from this study may help researchers develop more appropriate methods for crop variety evaluation that you can use to improve your farming practice.

Your participation in this study is completely voluntary. You do not have to participate if you do not want to, and you can refuse to answer any question. Even if you begin the study, you may quit at any time. If you do not participate or decide to quit, there will not be any negative consequences for you.

Will you be paid to take part, or will any expenses be covered?

You will not receive any monetary benefits by participating. We will however organize and pay for your lunch and pay your travel to attend the workshop if necessary.

Will you have access to outputs, and if so how?
If you want to, you may access the transcripts and images of your interview to make sure no reputation-damaging passages are included. We will also make all research results and anonymized data openly available at osf.io. We are happy to share a link to the results with you if you want to.

Why have you been invited to take part?
You have been invited to take part because you are participating (or chose not to participate) in ongoing farmer experimentation trials carried out by Bioversity International and Lutheran World Relief - Kenya.

Do you have to take part?
No, participation is optional. If you do decide to take part, you will be given a copy of this information sheet for your records and will be asked to complete a participant information form. If you change your mind at any point during the study, you will be able to withdraw your participation without having to provide a reason.

On what basis will we process your data?
Under the General Data Protection Regulation (GDPR), the University of York has to identify a legal basis for processing personal data and, where appropriate, an additional condition for processing special category data.

Personal data is defined as data from which someone could be identified. For example, in this study we will be collecting your name, gender and telephone number.

In line with our charter, which states that we advance learning and knowledge by teaching and research, the University processes personal data for research purposes under Article 6 (1) (e) of the GDPR:

Processing is necessary for the performance of a task carried out in the public interest

Research will only be undertaken where ethical approval has been obtained, where there is a clear public interest and where appropriate safeguards have been put in place to protect data.

In line with ethical expectations and in order to comply with common law duty of confidentiality, we will seek your consent to participate where appropriate. This consent will not, however, be our legal basis for processing your data under the GDPR.

How will you use my data?
Data will be processed for the purposes outlined in this notice.

Will you share my data with 3rd parties?
No. Data will be accessible to the project team at the University of York, Bioversity International and Lutheran World Relief only.

Anonymized data may be reused by the research team or other third parties for research purposes. To this end, we will make anonymized data available through a project website on the Open Science Foundation, osf.io.

How will you keep my data secure?
The University will put in place appropriate technical and organisational measures to protect your personal data. For the purposes of this project, we will not collect any directly identifying information as part of the interviews, observations, or questionnaire. Transcripts of interviews will be anonymized by deleting and/or replacing any accidentally shared potential personal identifying information (names, places, etc.) With anonymous placeholders. Field notes will likewise replace potentially identifying information with anonymous placeholders. On photographs, we will black out potentially identifying features such as location names or faces.

Information will be treated confidentiality and shared on a need-to-know basis only. The University is committed to the principle of data protection by design and default and will collect the minimum amount of data necessary for the project. In addition, we will anonymize or pseudonymize data wherever possible.

Will we transfer your data internationally?

Possibly. The University's cloud storage solution is provided by Google which means that data can be located at any of Google's globally spread data centres. The University has data protection complaint arrangements in place with this provider. For further information see, https://www.york.ac.uk/it-services/google/policy/privacy/.

***Will you be identified in any research outputs*?**
Any descriptions and individual quotes taken from interviews, field notes, or photographs will be presented in an anonymized form to prevent identification of any participant or linkage of any statement about practices with any individual participant.

How long will we keep your data?
Data will be retained in line with legal requirements or where there is a business need. Retention timeframes will be determined in line with the University's Records Retention Schedule.

What rights do you have in relation to your data?
Under the GDPR, you have a general right of access to your data, a right to rectification, erasure, restriction, objection or portability. You also have a right to withdrawal. Please note, not all rights apply where data is processed purely for research purposes. For further information see, https://www.york.ac.uk/records-management/generaldataprotectionregulation/individualsrights/.

Questions or concerns
If you have any questions about this participant information sheet or concerns about how your data is being processed, please contact the TFTV Ethics Chair (tftv-ethics@york.ac.uk) in the first instance. If you are still dissatisfied, please contact the University's Acting Data Protection Officer at dataprotection@york.ac.uk.

Right to complain
If you are unhappy with the way in which the University has handled your personal data, you have a right to complain to the Information Commissioner's Office. For information on reporting a concern to the Information Commissioner's Office, see www.ico.org.uk/concerns.

Bioversity International | Lutheran World Relief | University of York

Contact details:

Jeske van de Gevel: 020-7224511 or j.vandegevel@cgiar.org (Bioversity Int & University of York)

Philomena Wanza Simon (Joy): Joywanza9@gmail.com

Democratising farmer citizen science

CONSENT FORM

Please read the following questions and tick the appropriate box	Yes	No
Have you read the information leaflet about the interview process?	☐	☐
Have you had an opportunity to ask questions about the process and what your answers will be used for?	☐	☐
Are you aware that you can withdraw from this study at any time?	☐	☐
Have you been made aware of what will happen with the data (i.e. interview transcripts) collected from this study?	☐	☐
Do you confirm that you understand your right to confidentiality will be maintained?	☐	☐
Please confirm you have agreed to take part in this study	☐	☐
Please confirm you have agreed to be audio recorded	☐	☐
Please confirm you have agreed for photographs to be taken during the activities	☐	☐

Signed: ________________________

Date: __________________________

Bioversity International | Lutheran World Relief | University of York

Contact details:

Jeske van de Gevel: 020-7224511 or j.vandegevel@cgiar.org (Bioversity Int & University of York)

Philomena Wanza Simon (Joy): Joywanza9@gmail.com

Ethics committee at University of York: Anna Bramwell Dicks, tftv-ethics@york.ac.uk

Appendix 3: Murchan and Skjøtt's annotated designs

A Redesign of the Tricot Feedback Sheet

Naoimh Murchan & Jonathan Skjøtt

Executive Summary

The feedback sheet is given to farmers once a Tricot trial is done. It is meant to summarise the result of the trial as well as provide other useful information to farmers. This document proposes a redesign of the Tricot feedback sheet and provides insight into the prototyping process used to produce the proposed sheet. The following sections will address why it is necessary to redesign the feedback sheet, which feedback elements were designated as important based on an initial exploration of the design space, the field testing design of the different prototypes produced, annotated prototypes explaining design decisions, annotated portfolios explaining how users in the field experienced the different prototypes, the final form design, as well as areas which need further exploration.

Why a feedback sheet?

The feedback sheet is a cornerstone of Tricot. It is part of the final touchpoint in the Tricot service journey in which results of the trial is shared and discussed and future expectations for the farmers are set. Currently, the final touchpoint is skipped in some implementations, or participants only receive the feedback sheet. Tricot is meant to be a participatory methodology in which farmers are part of the research process from conducting a trial to looking and analysing the data. It is important to give meaningful results back to the farmers once they are done. Information which can help them decide on whether to continue growing the trialled crops or not.

Thank you for participating!

Maridadi Saidi Mdogo
Ligunga, Tunduru

These are the results of the experiment you contributed to.

You received the following varieties to rank:

Variety	Name
Variety A	NACH 2013
Variety B	Naliendele 09
Variety C	Mangaka 09

You ranked these varieties in the following order:

Characteristic	Best	Second	Worst
Germination	Mangaka 09	NACH 2013	Naliendele 09
Pest_resistance	Mangaka 09	Naliendele 09	NACH 2013
Disease_resistance	NACH 2013	Naliendele 09	Mangaka 09
Yield	Mangaka 09	Naliendele 09	NACH 2013
Value_in_the_market	NACH 2013	Mangaka 09	Naliendele 09

You compared the global performance of these Varieties with your Local Variety

Positions	Varieties
Position 1	NACH 2013
Position 2	Mangaka 09
Position 3	Naliendele 09
Position 4	Local Variety

These are the best and the worst Varieties you and observers with the similar characteristics received:

Positions	Varieties
Position 1	Naliendele 09
Position 2	NACH 2013
Position 3	Mangaka 09
Position 4	Pendo 98
Position 5	Mnanje 09
Position 6	Nachingwea 09
Position 7	Local Variety

Thank you for participating!

Figure 1.
The feedback form Tricot participants currently receive

Improving the information sheet is one of the key elements needed for improving the final touchpoint. As part of this aim we also tested out group activities to perform when this sheet is given out.

Form Format Exploration

This section discusses some of the elements that were explored before design of a complete sheet began.

Rankings

Rankings we used extensively in the original form. They are ideal for displaying data if there are relatively few data points. Extra graphic elements can be added to emphasise things.

Harvest 

Spinach	55
Kale ←	37
Amaranth	29
Onion	13
Tomato	5

Figure 2.
A ranking

1

Bar plots

These graphics associate data with the height or length of a bar. They offer a simple way to visualise both positive and negative space. This is done in the bar plot below. You see how many farmers would grow the crops again, but also see how many would not grow it again.

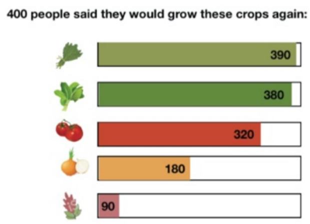


Figure 3.
A bar plot

Icons

The user group the feedback sheet is for can be described as a low literacy population. It cannot be assumed that all users effortlessly read and understand all sentences, symbols, and data visualisations. Realistic icons, if well designed, is an effective way of support meaning making. Instead of only writing the names of crops or metrics icons can be added along the writing to increase understanding.

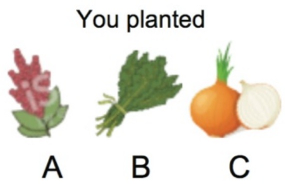


Figure 4.
three icons for crops

Certificates

Tricot seems to be a case in which offering some kind of social recognition after a trial might engage the user group. The final touchpoint of the Tricot service journey is a great point in Tricot to hand out a certificate. This was inspired by our knowledge of the Juicy feedback game design lens.

Figure 5.
example certificate text

Crop specific growing information

Given out as individual cards or as part of a larger form specific qualitative feedback provides rich insights about a specific crop. It stands in constrast to the exclusively quantitative data traditionally collected in Tricot.

Figure 6.
cards containing growing information

Visual identity for different crops

We have tried to make the varieties easier to differentiate by making associations with colours, patters, or symbols. Varieties are usually very similar which creates a need for differenting them by other means than their looks.

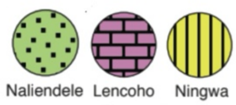


Figure 7.
examples of visual identities

Field testing plan

First round - 10th of August

Participants were asked to gather in groups of two around one of us and a translator. One participant will read through the sheet and be prompted for their thoughts on how they interpret it to the two researchers observing them. Two participants who've read through two different feedback sheets will explain their sheets and discuss their thoughts on the two. After all pairs had explained the forms to each other the group discussion was initiated. We asked them about their thoughts.

Second round - 15th of August

Having created a second iteration of the feedback sheets, we tested the second iteration of the sheets following the method 10th of August.

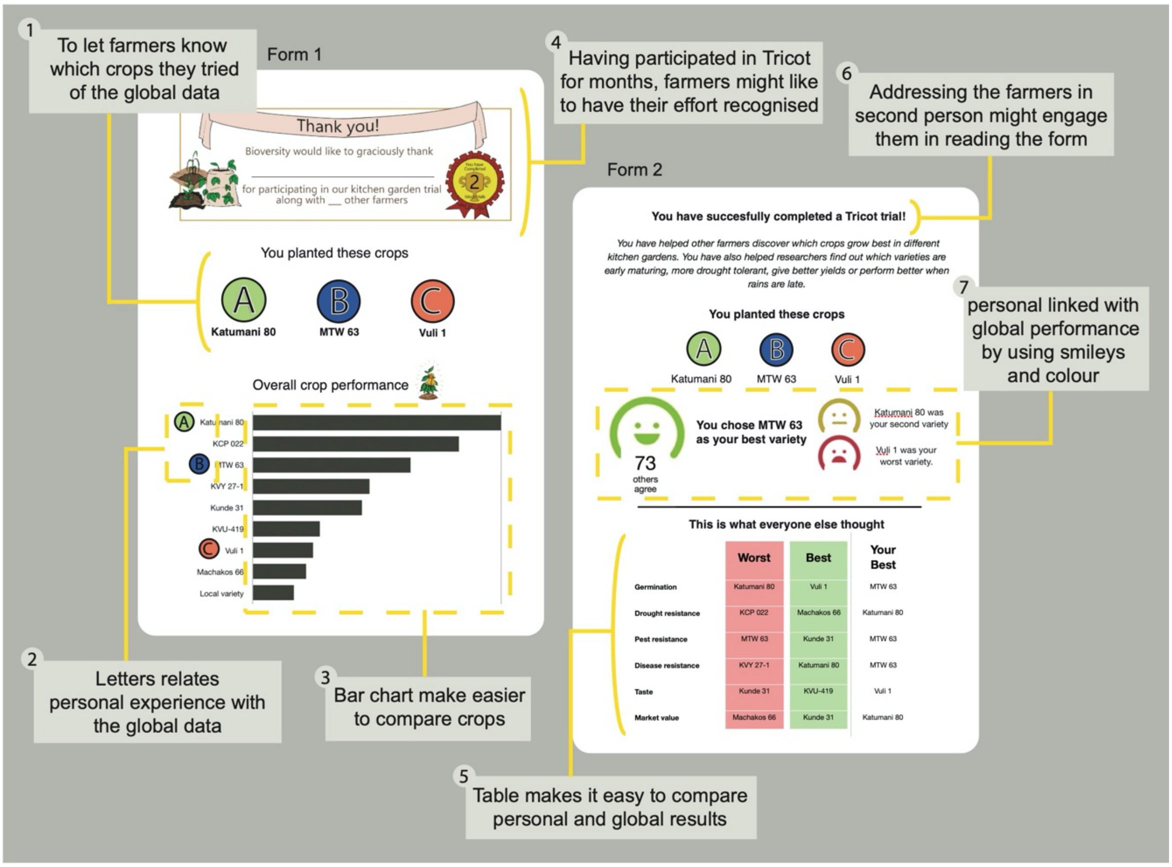
Third round - 16th of August

Gathering a group of six participants, we split them into pairs and gave each pair one type of feedback sheet, one from the previous round(Form 1), and the two new iterations (Form 3 and Form 4). We gave these pairs some time to discuss, read and analyze the forms they had been given before they would all gather together and been shown and explained to the best of the pairs abilities. The group would then discuss which forms they liked better and why. We did two rounds of this activity using the same method.

Annotated prototypes

The following pages will present annotated feedback sheets for all the sheets trialled in the field as well as the latest iteration. Annotations with yellow lines provide explanations of design decisions which were made. Annotations in blue provide comments on how participants engaged with elements of the sheets. They are presented in chronological order starting with the v1 forms used for the first round of testing, then the v2 forms which were used for round two and three, and finally the final redesign based on all the things learnt from the field activity.

2



Annotated v1 sheets design decisions

These two feedback cards are the first pair which were tested in the field. Below are specific comments on elements of the forms.

①

To let farmers know which crops they tried of the global data. A goal with the feedback sheet is to allow farmers to compare the crops they tried with all the crops tried by all the farmers. For that to happen effectively an association has to be made which allows farmers to locate the varieties they tried in visualisation of all of the data. In the first iteration this is done by linking a uniqur color and letter to each ot the varieties the farmer tried.

②

Letters relates personal experience with the global data. These letter are meant to draw attention to the crops which the farmer has tried out of the ones visualised.

③

Bar chart make easier to compare crops. The bar chart makes it possible for the farmer to better compare the crops than if they had just received a ranking. This plot was partially added to see whether they would understand the data better if introduced in this form instead of representing the it with a table.

④

Having participated in Tricot for months, farmers might like to have their effort recognised. Farmers would most likely be glad to have their dedication to making the trial on their land happen recognised. A certificate of completion or appreciation is a good object which will stay with the participant after the trial is done.

⑤

Table makes it easy to compare personal and global results. With adjacent rows displaying the farmers own choice versus the global ranking farmers will be able to compare and contrast the data for several dimensions.

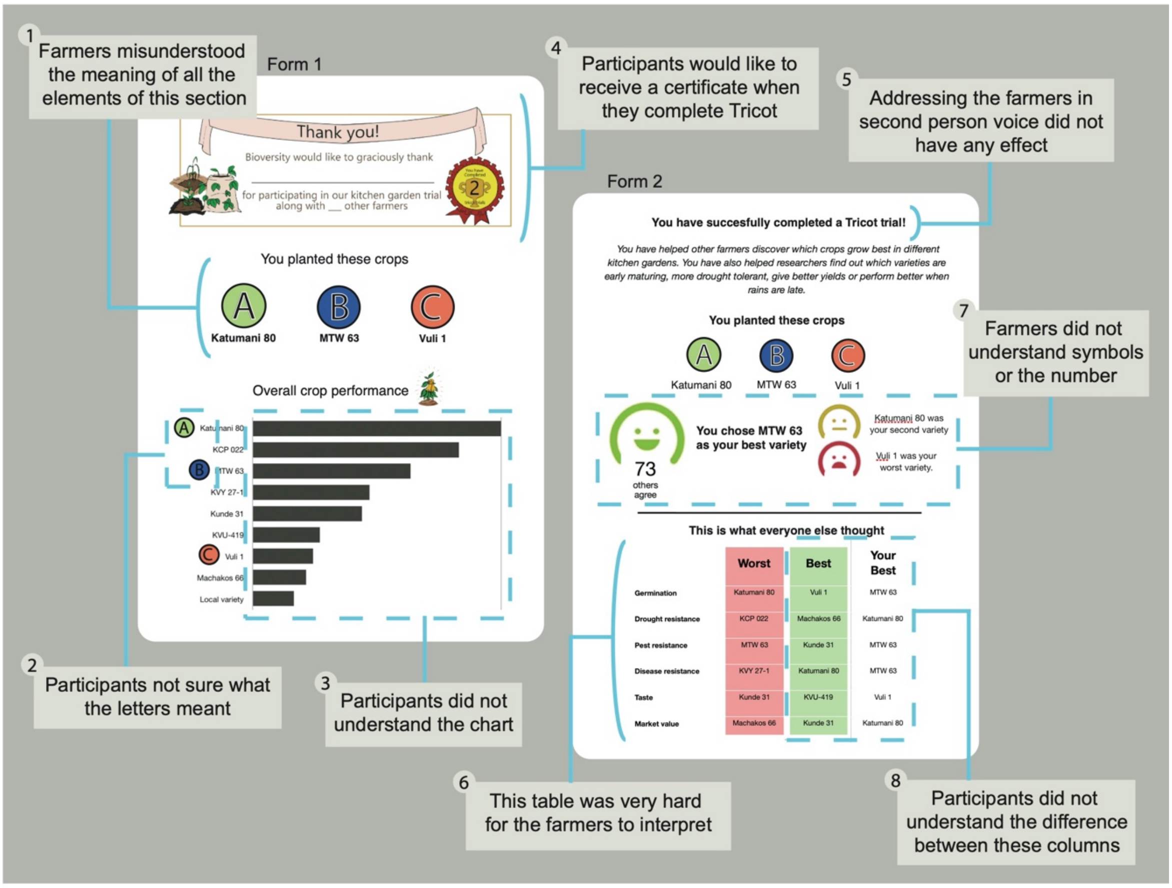
⑥

Addressing the farmers in second person might engage them in reading the form. Care was put into consistently addressing the farmer directly and presenting results in relation to the farmers own experience.

⑦

personal linked with global performance by using smileys and colour. In this section the way the farmer filled in the form is read back to them and the number of farmers who agree with their choice is presented to them.

3



Annotated v1 sheets user experience

①

Farmers misunderstood the meaning of all the elements of this section. It was really hard for the farmers to understand that the letters indicate which crop the farmers tried themselves. They did not seem to pay much attention to the title of the section.

②

Participants not sure what the letters meant. Some farmers thought the letters designated groups of crops which performed best. Others just did not know what they meant.

③

Participants did not understand the chart. The farmers did not associate the bars with data. They were not sure why the dark bars were there or why they had different size. They were also not sure about which dimension it was supposed to display.

④

Participants would like to receive a certificate when they complete Tricot. When asked about whether they would like to receive a token of appreciation the farmers always indicated that they would like that.

⑤

Addressing the farmers in second person voice did not have any effect. Using this tone and trying to address farmers directily was never noticed by farmers. They seemed to mostly skip larger sections of text.

⑥

This table was very hard for the farmers to interpret. The title of the graph was not helpful to them at all. It seemed to be too saturated with information form different data sources.

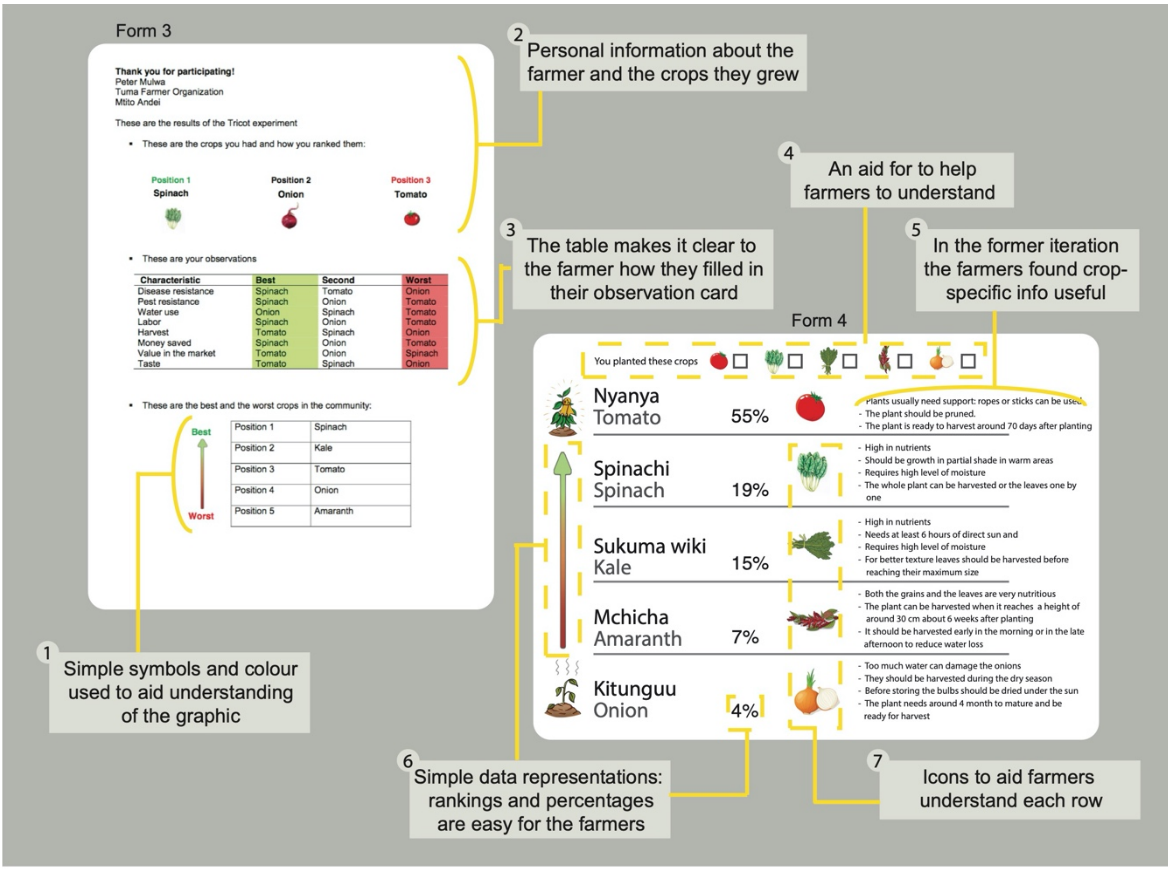
⑦

Farmers did not understand symbols or the number. This visual was inspired by gamified sites on the web. Having some kind of tracker indicate your choices or preferences while also providing some global data on the performance of other people having similar performance to the user. The farmer seemed to glance over this section. None understood what the number describing the number of farmers aggreing with the farmers. The smileys did not seem to support meaning making.

⑧

Participants did not understand the difference between these columns. Both columns had best in them and they seemed to not realise how one of the columns represented their own data.

4



Annotated v2 sheets design decisions

①

Simple symbols and colour used to aid understanding of the graphic. Though this was not part of the original form we wanted to include some of the same elements in both of the forms. We did not want this to be a comparison between a form without with on which has graphics. We wanted the kind of data given to be evaluated.

②

Personal information about the farmer and the crops they grew. In the original form as well as this slightly altered one the first section of the form is framed very much like a letter. We wanted to test if the farmers valued this way of framing the feedback card.

③

The table makes it clear to the farmer how they filled in their observation card. Throughout Tricot, informing farmers about their past choices has been the standard. However, we were not sure about the extent to which farmers understand or appreciate receiving this data.

④

An aid for to help farmers to understand . When the farmers receive this card we would put a cross for the crops the farmer tried. The aids we gave farmers when testing other forms had been really useful to the farmers. Therefore we wanted to test whether an aid with similar design.

⑤

In the former iteration the farmers found crop-specific info useful. In fact they found that information much more useful than any of the global results. Therefore, we decided to dedicate 2/5 of the space on the page to giving the farmers detailed information.

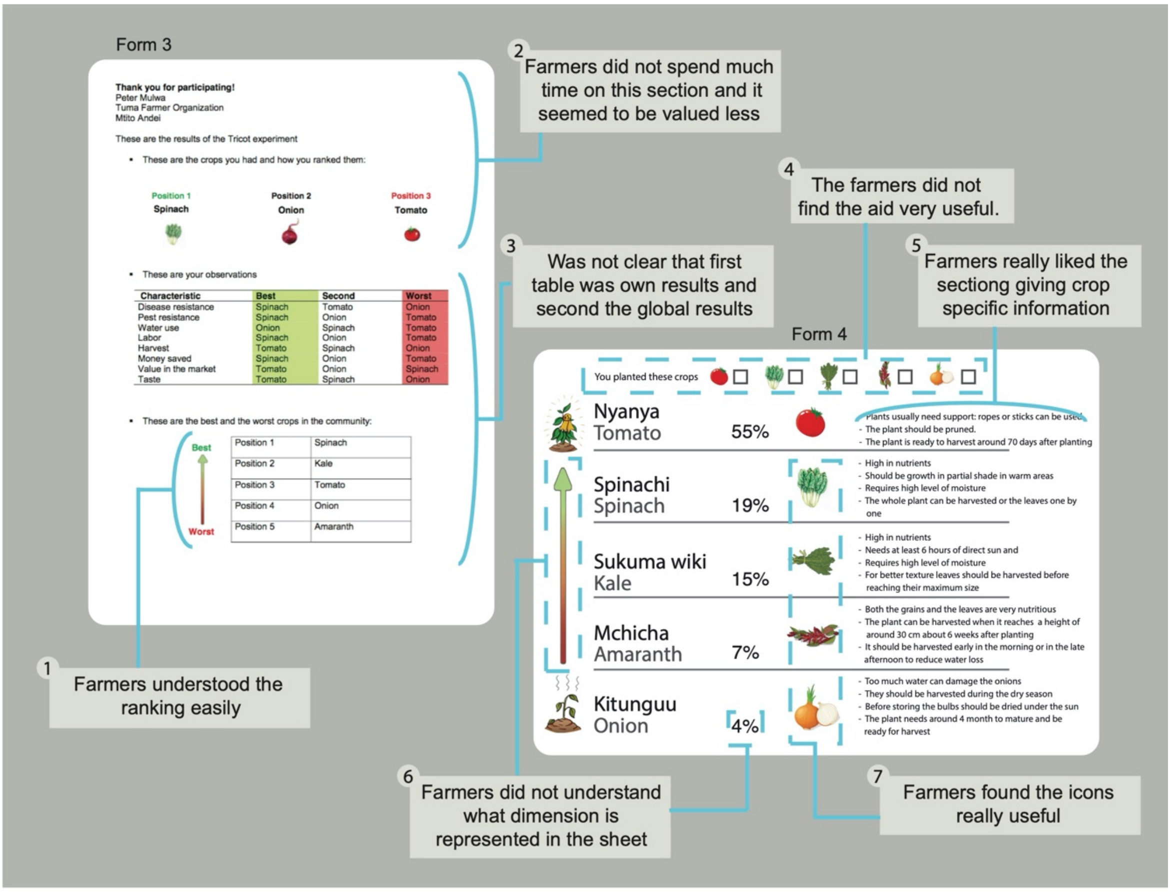
⑥

Simple data representations: rankings and percentages are easy for the farmers. The more advanced graphs tested in the first iteration were very hard for the farmers to understand. We tested all the data representations we decided to use in this iteration to make sure that they understood the data representation format well.

⑦

Icons to aid farmers understand each row. Throughout all of our field work the icons have always been really helpful. They help all farmers understand concepts and are helpful to farmers who are intimidated by the many words.

5



Annotated v2 sheets user experience

①

Farmers understood the ranking easily. When prompted the farmers understood that this section contained a ranking of the crops which were tested in the current trial. Any issues in understanding the information in the graph would be due to other factors making the graph confusing.

②

Farmers did not spend much time on this section and it seemed to be valued less. Many farmers seemed to just glance over or completely skip this section. They did not actively use the information contained in this section as they went through the rest of the form.

③

Was not clear that first table was own results and second the global results. This was confusing to the farmers. The two graphs look visually similar, but the nature of the data is very different. One is only personal preferences, the other is global data. The small titles, lack of icons are probably two things contributing to this section working poorly.

④

The farmers did not find the aid very useful. As they knew what they were growing having an aid to remind them seemed very redundant. As farmers could easily differentiate the crops tested in the implementation of Tricot our farmers participated in, it was difficult for us to test aids of this nature.

⑤

Farmers really liked the sectioning giving crop specific information. The large majority of the farmers really liked receiving specific and detailed feedback from an expert or the researcher working with a crop or variety.

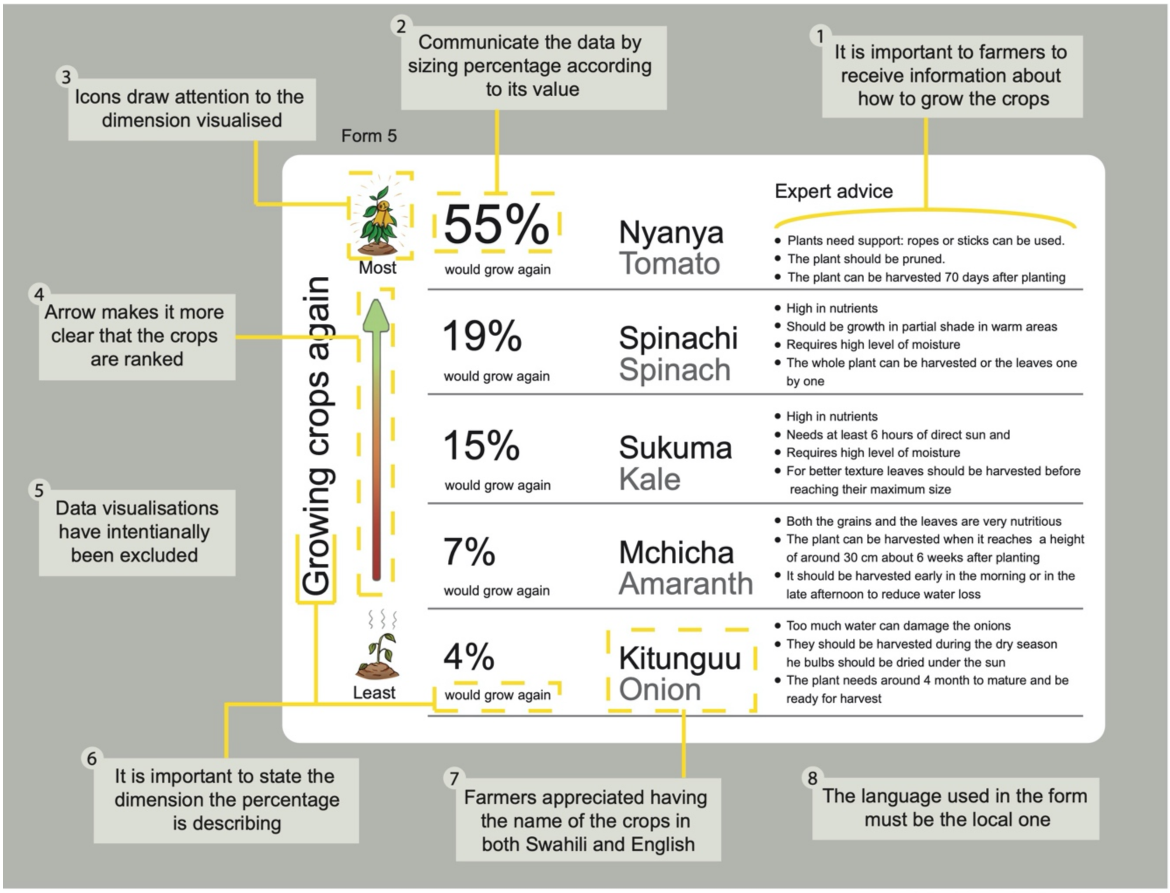
⑥

Farmers did not understand what dimension is represented in the sheet. They did not know what the arrow meant. They understood the percentages as a unit, but did not know what the dimension the percentages represented. They needed a title or something designating what the data represent.

⑦

Farmers found the icons really useful. They made the sheet much more glanceable. Together with the name of the crop in two languages the farmers were completely sure about which crop the information in the rows were tied to.

6



Annotated v3 sheet design decisions

①

<u>It is important to farmers to receive information about hot to grow the crops.</u> This is the section that the farmers found most useful. They want specific, qualitative, and context-specific information about the varieties they are growing. The first feedback sheet we tested in the field had this section hidden away on the second page. What stood out and made us decide to give it about a third of the space in the final iteration of the sheet was that farmers throughout located this section as the most useful one.

②

<u>Communicate the data by sizing percentage according to its value.</u> During the field days, it became clear that it was hard to present statistical information to the farmers. Changing the font size of the number based on the data the number represent is a way of associating space with data in a way which does not require much knowledge of data visualisation. Farmers understand percentage well as a concept .

③

<u>Icons draw attention to the dimension visualised</u> Farmers found the icons very useful in all activities. If they have trouble reading the sentences the icons aided them in understanding what is being asked, answered, or visualised.

④

<u>Arrow makes it more clear that the crops are ranked.</u> The ranking is a representation of data which the farmers can understand. The feedback sheet is ordered according to the different crops' performance in the dimensions. However, this may not be completely clear. The arrow is meant to act as an aid for the farmers to better grasps that the whole sheet is ordered as a ranking.

⑤

<u>Data visualisations have intentianally been excluded.</u> We tested several feedback sheets in the field which contained histograms, rankings, and bar plots. In general, the visualisations are not understood. Also, they generally value qualitative data more.

⑥

<u>It is important to state the dimension the percentage is describing.</u> Whereas the farmers can easily think in terms of percentage, they had very few ideas about what the percentage ranking meant if no labels were provided describing what the data represent. The title is meant for the sheet to be glanceable, the description underneath the data values act as direct support for participants when they try to read the data.

⑦

<u>Farmers appreciated having the name of the crops in both Swahili and English.</u> Some of them seemed to learn new words this way. Others just thought it would increase the number of farmers who would understand the form.

⑧

<u>The language used in the form must be the local one.</u> This is supported by research in form-design and our fieldwork. The language of forms and materials must be in the language they are most familiar with.

7

A Redesign of the Tricot Observation Card

Naoimh Murchan & Jonathan Skjøtt

Executive Summary

The observation card is a vital part of the Tricot process, given to participants when they begin the trial. In some cases it is filled out several times throughout the process, and should be filled out by the participants themselves. It is the core way data is collected from the farmers, giving them a voice in Tricot. The following document will explain why we decided to redesign this form and the steps and thoughts we took to get to our final iteration.

Figure 1.
Previous versions of Observation Cards participants have recieved.

Why an observation card?

We decided to prototype and test the Observation Card after getting a better overall view of Tricot, its method, users and implementation. Having seen a lack of consistency between trials regarding what form is used and how the researchers go about making them, we wanted to see if we could get solid data about what forms actually worked well in these environments. This seemed easy enough to work and iterate on before our trip to Kenya, and would be relatively simple to test in the field using observation and note taking.

Form Format Exploration

These are some of the different ways we explored and approached design different parts of the observation card.

Letter Input

Following on from the initial tricot form we had been introduced to, we explored around the idea of the user inputting the crop associated letters. While the original form we took inspiration from had the user inputting only two of the three letters side by side, we experimented with inputting all 3 letters.

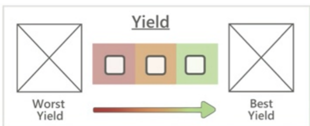


Figure 2.
Letter Input exploration.

Then returned to only inputting two letters, having space in the middle to try and create a distinction between the questions.

Checkboxes

Taking some inspiration from the other form being used in the most recent Tricot trial we experimented with laying out questions that used checkboxes instead of asking for written letter inputs. We tried out a few different layouts to see which seemed the

1

the most simple and intuitive to fill out.

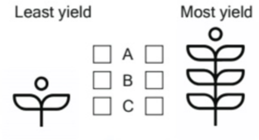


Figure 3.
One of the check box style layouts based on an initial observation cards layout.

Question Size

One important factor in designed the two different forms to test in the field was having the varying question size. While the previous version on the field tried to condense each dimension into one question, and the form before that sought to create a close relation between two questions by having the inputs very close together, the new forms tried something different. We wanted to experiment with space and having things more clearly separated out, but still have a sense of relatedness between them. With Form 1, this resulted in trying to tie things together using visual elements like an arrow. While in Form 2, we had two distinct questions, only associated by row. However we still did look into other layouts throughout the prototyping process.

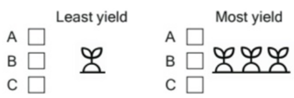


Figure 4.
Mock up of possible layout where questions become more separated.

Colour Use

In the design process we looked at including colour to give more meaning, mostly focusing on using red and green for positive and negative associations.

As well as this, when making some of the icons some consideration was given to trying when we could to make the icons understandable and readable both to colour blind individuals and when printed with black and white printers.

Icons

We decided to create custom icons for the forms, after initially using some stock images found online. The custom icons were much easier to tailor to our specific meanings and needs, as finding specific, cohesive icons otherwise proved very time consuming

Line Drawing

One other input method that was mocked up was drawing lines between the crop letter and ticks and crosses. However the lack of visuals to guide the question itself, and the unfamiliar input type meant that we decided not to take this idea any further.

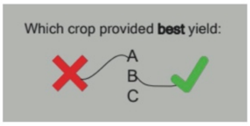


Figure 5.
Visual example of line drawing.

Coloured Pens

Another input method we conceptualised was using coloured pens to mark the best and worst crops, using some of our colour focus from earlier. However as this seemed rather more resource intensive and very much relied upon the participants reliably looking after these resources, we also did not decide to move further with this.

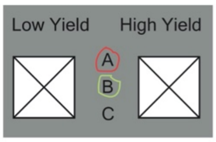


Figure 6.
Visual example of using coloured pens.

Instructions

One of the last things we looked at was introducing instructions on the front page to show the user how to fill out the form. We looked at other simple displays of form filling instructions which usually involved showing a hand and an already filled form. We simply adapted this to our own forms, although one of the other explorations did have some instruction explorations, due to its differing nature from the other forms.

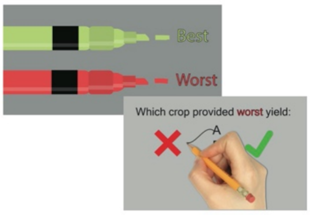


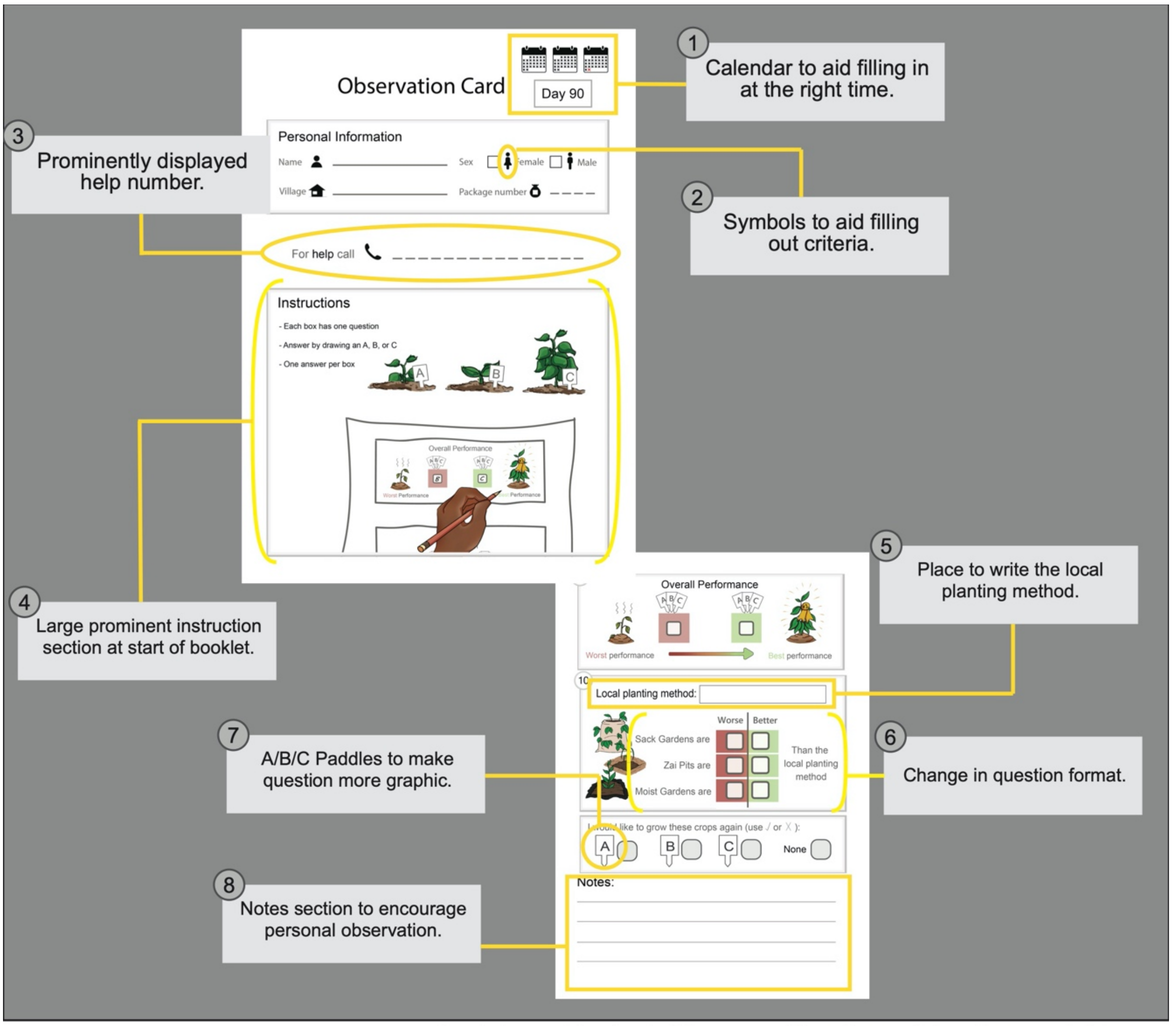
Figure 7.
Exploration of instruction methods.

Field testing plan

Participants were observed by two people as they filled in the forms, prompted at various points for their thoughts and opinions. They were then asked to explain their form version to a participant who had the other form and vice versa. Original plans included a stage after this where their card would be read back to them to verify their intentions and interpretations of the form. On the field we then had a brief group discussion.

Annotated prototypes

The following pages will present annotated observation cards for all the sheets trialled in the field as well as the latest iteration. Annotations with yellow lines provide explanations of design decisions which were made. Annotations in blue provide comments on how participants engaged with elements of the sheets.



1

Calendar to aid filling in at the right time. As in some trials the farmers have to fill out at specific time we thought visual representation of a calendar on their sheets could aid with this.

2

Symbols to aid filling out criteria. In order to aid the farmers in filling out this section, who may not read the language used we included simple standard symbols to try and help this.

3

Prominently displayed help number. In the case where farmers may need help filling in the form or with the trial in general, this number is prominently and obviously displayed for them to call and get help.

4

Large prominent instruction section at start of booklet. The instruction section is here at the front of the booklet rather than the back so the farmers can see it before they see the questions themselves. The instruction section itself is meant to mimic the process the farmers will go through on the field. Three labeled plants are shown while someone holds a page of the form, to mimic them making observations on the field. Meanwhile a hand is shown holding a pencil on the form, to show that it has just been filled in just then.

5

Place to write the local planting method. Similarly to its predecessor forms, there is a place to write the name of the local method. Here the text around it is stripped down to be simpler.

6

Change in question format. Due to the question being asked, the format of the question has changed, in a similar fashion to the original form. Here the participant is expected to tick one box on each side to essentially complete the sentence.

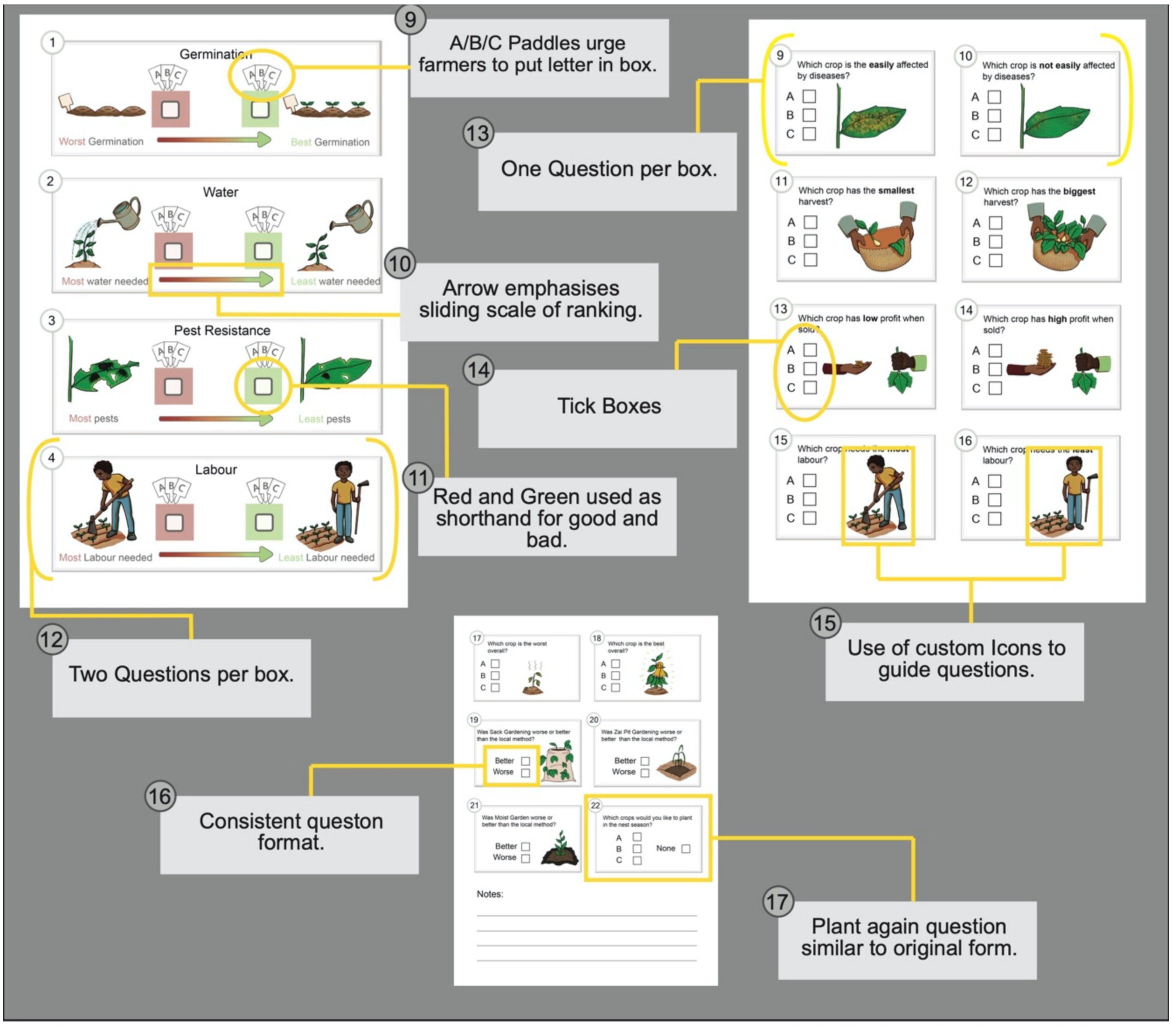
7

A/B/C Paddles to make question more graphic. The grow again question had not previously been very visual and is unlikely to be able to be due to the plants all looking very different. This was a way to try and make the question slightly more visual and help guide the participant using familiar graphics.

8

Notes section to encourage personal observation. Having heard that in previous trials, giving the participants notebooks in which to take further notes had been quite successful, we thought having a personal notes section of the sheet would be a good way to make it seem more personal and give room to make further personal observations.

3



(9)

A/B/C Paddles urge farmers to put letter in box. The use of the A/B/C paddles, who have bases pointing toward the box itself is meant to illustrate further for the farmers to put one of those letters in that box. The paddle shape used is meant to mimic that used in the instruction section.

(10)

Arrow emphasises sliding scale of ranking. Arrow is meant to help correlate the two boxes tw o each other and show they are a scale from worst to best.

(11)

Red and Green used as shorthand for good and bad. The red and green boxes in assoc iation with the illustrations should help show the participant that they represent the best/worst crops.

(12)

Two Questions per box. By having the two questions within the box we can create an easier association between the question topic and try to rely on this to explain some of the question.

(13)

One Question per box. We decided to separate out each question into its own box in this version of the form to see if breaking things down into simpler separate parts made the form easier to understand.

(14)

Tick Boxes. To deviate away from previous versions we had seen this form instead of asking the partici- pant to fill in a letter simply asks them to fill in a box.

(15)

Use of custom Icons to guide questions. Custom icons were created for the different dimensions to better illustrate what was being asked of the farmers.

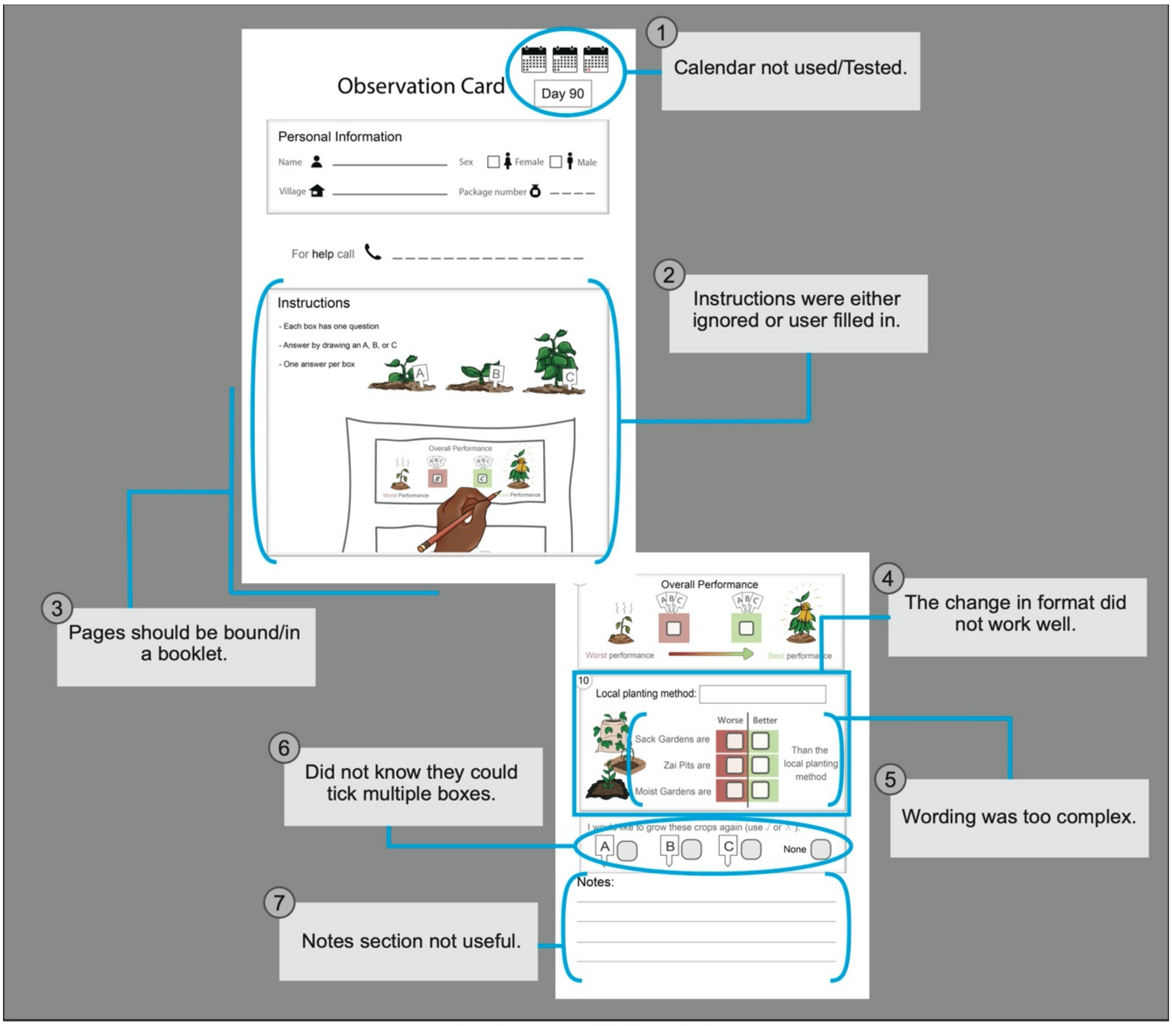
(16)

Consistent question format. In order to not confused the partici- pants the method of answering these later questions does not change and they are similarly broken down into component parts.

(17)

Plant again question similar to original form. Like the original form you have the option to tick as many of the three boxes or none, however the layout here is changed to try and emphasise you can tick many on the left or the one on the right, to see if this could be felt intuitively when tested on the field.

4



(1)

Calendar not used/Tested. Due to the way these forms were tested we did not get to see if this concept was at all useful, as it was not relevant to the current trial. However participants still did not seem to pay much attention to it.

(2)

Instructions were either ignored or user filled in. The Instructions seemed to confuse several participants, especially those using Form 2, as they began to fill in the instructions, marking boxes. Otherwise participants tended to ignore the instruction section, quickly turning over to start filling out instead.

(3)

Pages should be bound/in a booklet. On the field, the forms used were loose sheets. The participants when presented with these would often need to be prompted to turn over pages or they would simply stay on one sheet, on one side the whole time.

(4)

The change in format did not work well. Participants found the change in filling out the form (moving from filling in letters to ticking) quite confusing and did not fill in the form right in most cases, often leaving this question blank.

(5)

Wording was too complex. Participants stated that the language and structure used here was overly complex, especially as they could not read much english.

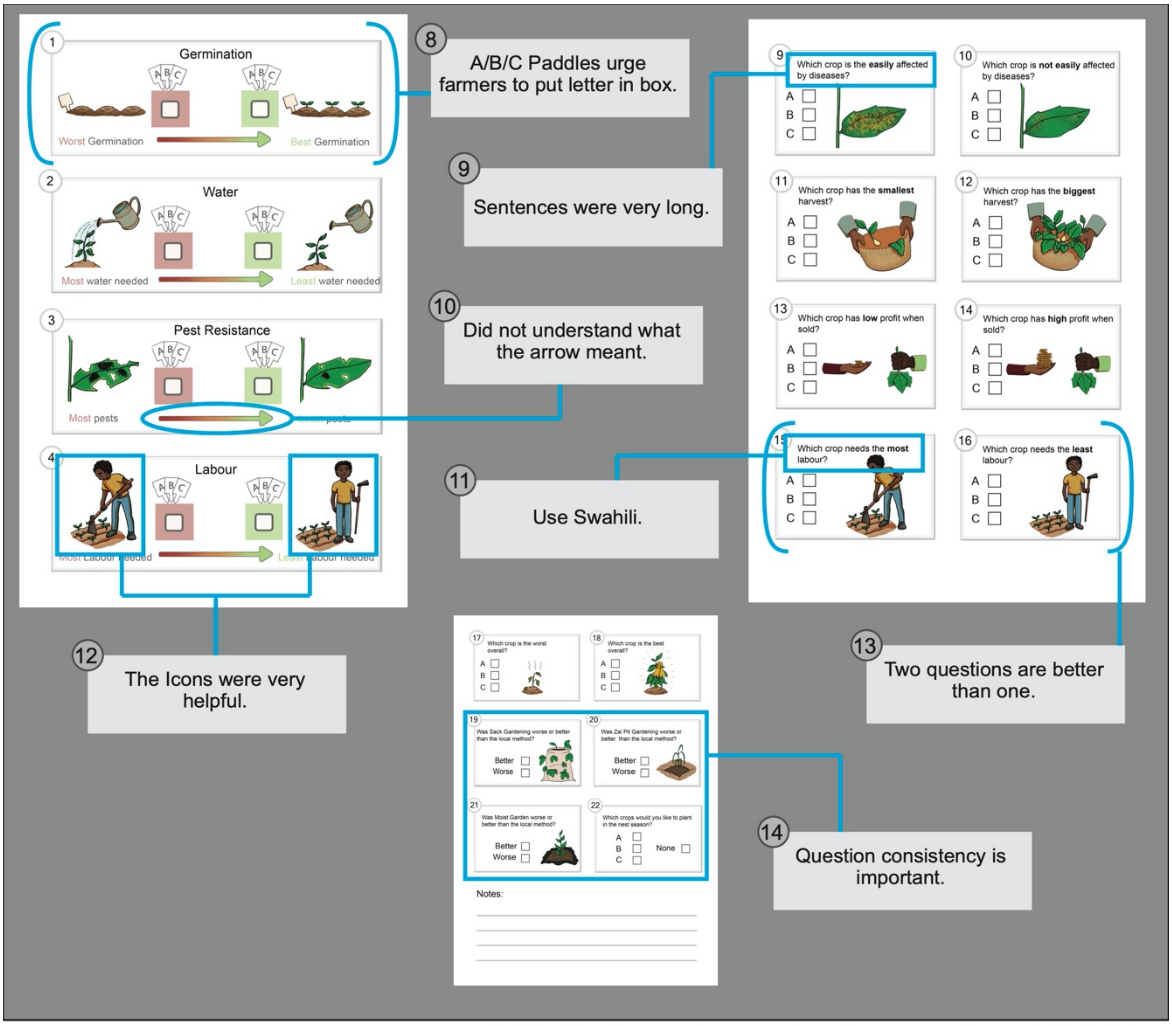
(6)

Did not know they could tick multiple boxes. The participants who could fill out this section often did not realise they could select multiple crops they would like to grow again until prompted. This needed to be better conveyed in the question.

(7)

Notes section not useful. This section was not used at all in testing, and it seems it would be unlikely to be used in practice, as the participants seemed to consider the cards important and were unlikely to use it simply to write notes for themselves. It seems if researchers wanted this they would do better to provide notebooks.

5



(8)

Icons and Wording need to be carefully considered. The ‘Germination’ question was not understood well in the field on either form, the concept seemed foreign until explained, the words used were not helpful and the illustrations did not easily present the concept. So while images are important, one must use and consider them carefully.

(9)

Did not understand what the arrow meant. This had no significance to the participants.

(10)

Sentences were very long. The sentences on Form 2 were mentioned to be very long for the participants, especially considering their limited knowledge of english.

(11)

Use Swahili. Most participants commented that the forms and sheets would overall be much easier to digest if they could be translated to Swahili, a language they can read much more easily.

(12)

The Icons were very helpful. Due to often some illiteracy and lack of being able to read english, the participants often relied on both the words and their association to the pictures to fully grasp the concept of the questions.

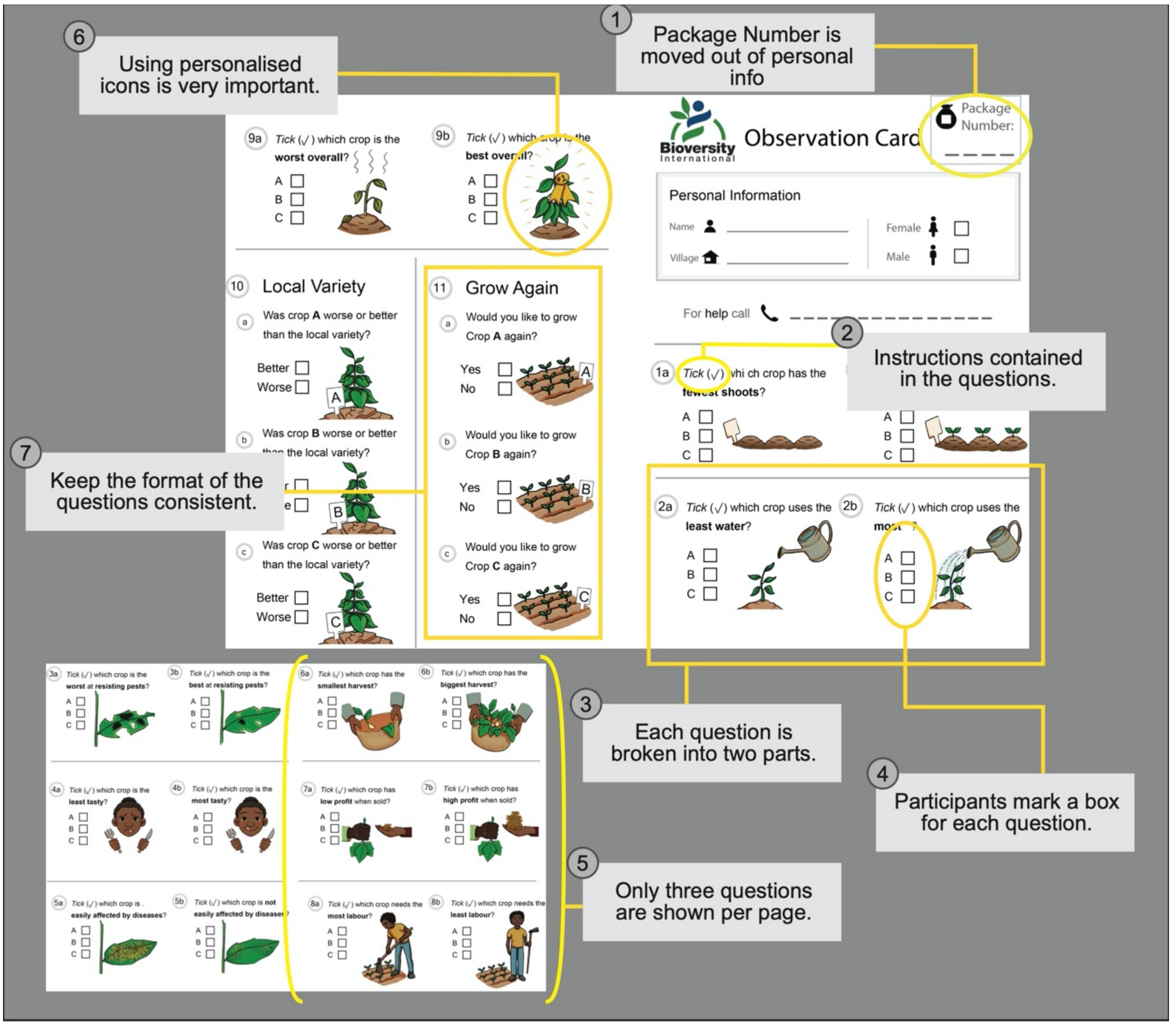
(13)

Two questions are better than one. It seemed Form 2’s breakdown approach was overall easier for the participants to understand.

(14)

Question consistency is important. Form 2’s final questions approach, of both having separated simple questions with the same method of filling in was much better for these later questions. Users did not have to make any great jumps in logic but could simply continue what they were doing previously.

6



① **Package Number moved out of personal information.** In most Tricot trials this will be filled out for the farmers by the implementers, therefore it does not make sense to have it in an area we otherwise expect them to fill out for themselves.

② **Instructions contained in the question.** When testing we found the farmers often either ignored the instruction section completely or confused it as being a part of the form, at which point they would begin to fill it in. As ticking seemed quite intuitive to them, we have included only a short directive at the start of each question.

③ **Each question is broken into two parts.** Having two questions to answer at once as in previous versions seemed more difficult for the farmers to quickly grasp. Breaking each question down into its separate parts seemed to work better.

④ **Participants mark a box for each question.** Farmers intuitively were able to tick boxes when testing the forms, compared to often struggling when trying to fill in letters. Testing on other materials in the field often revealed the farmers ticking on sheets where they were not even supposed to fill something in, showing their inclinations towards these types of input methods.

⑤ **Only three questions are shown per page.** When testing the farmers clearly expressed the desire for both larger icons and larger font sizes to aid them in reading the forms. Less questions per page leaves more room to increase these sizes and readability.

⑥ **Using personalised icons is very important.** The icons aided greatly in the farmers understanding the forms, appropriately tailored icons should be used to portray ideas in as relevant a manner as possible.

⑦ **Keep the format of the questions consistent.** When testing on the field, changing the format, such as the style of the question (filling in a letter versus ticking a box) or changing the amount of inputs you desire (checking one box versus checking multiple boxes) lead to more confusion and resulted in the farmers not filling out the form correctly or properly expressing their answers to the questions. For this reason the last two questions in the form are each split into 3 distinct questions, ensuring the method of input stays the same and leaving less room for mistakes.

7