RESEARCH PROJECTS

Using Citizen Science to Explore Plant Breeding and Investigate Food-Chain Transparency for Novel Breeding Methods

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Summary

The UK recently investigated the potential use of biotechnology to improve environmental sustainability and stimulate innovation in plant breeding technologies. As a result, a Bill that defines some types of gene editing as 'precision bred organisms' became law in England in March 2023. This was followed by a public consultation exercise by the FSA that sought stakeholders' views on proposals for the new framework in England for regulating precision bred organisms used for food and animal feed.

Building upon the efforts of policymakers, regulatory agencies, and previous research that underscored the pivotal role of public acceptance, knowledge, and trust in the successful implementation of novel technologies, this research aimed to investigate UK citizens' views on traditional versus novel plant breeding methods. To achieve this, we used citizen science, an innovative participatory research method. Our approach to citizen science in this project involved volunteers in our research to benefit them but also to benefit the research community, regulatory agencies, and policymakers so their participation ultimately leads to fruitful outcomes and widely accepted policies.

The project aimed to improve citizens' knowledge of traditional and novel plant breeding methods and understand citizens' needs regarding a transparent food system that involves implementing novel technologies, including gene editing. Therefore, 69 citizen scientists were recruited via project partner Universities' social media channels and alums networks. The research consisted of online exercises, surveys, feedback collection, and focus groups.

The results suggest that the engagement and educational exercises during the study had improved citizen scientists' knowledge of traditional and novel plant breeding methods. Nearly all reported that they learned about plant science and about how fruits and vegetables were grown (from a low original baseline). Their moderate level of trust in regulatory agencies did not appear to be influenced by this increase in knowledge. No consensus was found regarding citizens' views about the transparency in the food supply chain and labelling of gene-edited fruits and vegetables. This indicates a need for further research with citizens to explore their understanding of transparency and conditions under which they would support or not support labelling.

Executive Summary

Context

Plant breeding has been practiced for thousands of years to produce genetically improved species; for example, to make precursors of today's well-known crops such as maize, wheat, and apples more resistant to diseases, higher yielding, and more nutritious. Gene editing is a novel plant breeding method resulting in genetic changes equivalent to those used in traditional plant breeding. However, it is more advanced than both traditional breeding and genetic modification (where foreign DNA is added) because the genetic changes are controlled and targeted.

After EU Exit, the UK signalled its intention to diverge from some EU laws that require more regulation compared to many countries in the world. This divergence also included plant breeding, particularly the use of biotechnology to improve environmental sustainability and stimulate innovation in plant breeding technologies. A Bill that defines some types of gene editing as "precision bred organisms" completed its passage through both Houses of Parliament on 6th March 2023 and received Royal Assent on 23rd March 2023. FSA completed a public consultation on 8th January 2024 to seek stakeholders' views including consumers on proposals for the new framework in England for the regulation of precision bred organisms used for food and animal feed.

Previous research suggest that the implementation and continued use of novel technologies partly depend on public acceptance, and that knowledge and perceived trust (e.g., in institutions and supply chains) influence public acceptance via risk perceptions and benefit perceptions (Bearth & Siegrist, 2016; Kaptan, 2018).

Improving consumer knowledge can be achieved gradually with deliberative, participatory, and transparent approaches. Citizen science, an innovative participatory research method, has potential to help successful implementation of novel food technologies. Citizen science requires volunteers' active involvement in scientific research, to benefit both them as informed consumers, and the research community and policy makers, enabling better informed policy development.

By reflecting citizens' views on traditional and novel plant breeding methods through citizen science, this research is timely and supports FSA's efforts for the UK citizens to ensure safety, informed decision making, and responsible use of precision breeding techniques.

Objectives

This project aimed to apply a citizen science methodology to achieve two primary objectives. Firstly, to improve citizens' knowledge of traditional and novel plant breeding methods. Secondly, to better understand citizens' needs regarding a transparent food system that involves implementation of novel technologies including gene editing.

Methodology

We applied both contributory and collaborative citizen science methodology. Our contributory approach involved designing a data collection exercise for citizen scientists, as a first step of building a future database for gene-edited fruits and vegetables. Our collaborative approach enabled citizen scientists to interact with and provide feedback to us throughout the project, which helped us adapt educational videos and evaluate the project process and outcomes.

Key Findings

We improved citizen scientists' knowledge of both traditional and novel plant breeding methods. Our post-participation survey found that our engagement and educational exercises had improved citizen scientists' knowledge of both traditional and novel plant breeding methods. Nearly all reported that they learned about plant science and about how fruits and vegetables were grown (from a low original baseline). Most participants when tested were now able to provide some accurate information about both traditional and novel plant breeding methods. Additionally, about 2/3 said they learned about the government's role in labelling.

We aimed to better understand citizens' needs regarding a transparent food system that involves the implementation of gene editing. The surveys conducted pre- and post-participation found that while most citizen participants trusted UK regulatory agencies such as FSA to ensure that the fruits and vegetables which consumers buy is safe, simultaneously most did not think the food supply chain in the UK is transparent in terms of how the food they buy is grown. About 3/4 thought that fruits and vegetables produced with novel technologies should be labelled, even if there was a public register of approved gene edited foods.

Focus group discussions corroborated these findings on trust but did not reach a consensus on transparency and labelling. Responses were slightly different in the focus groups because some participants said they might not need gene-edited foods to be labelled if they had been confirmed as safe to eat by a trusted organisation.

Overall, citizens wanted to know more about how the fruits and vegetables they buy are grown, and wanted this information to be more transparent. Future research should investigate whether actual and/or perceived transparency of the food system (regarding implementation of gene editing) reduces demand for labelling (of gene-edited fruits and vegetables).

Reflections on Citizen Science

We applied a contributory and collaborative citizen science methodology. Citizen scientists reported that a data collection exercise at the start of the project helped them realise how unfamiliar they were with conventional plant breeding methods, as well as the growing processes of fruits and vegetables, let alone novel plant breeding methods, which motivated them to engage with the learning material.

Citizen scientists' feedback, from responses to the pre-participation survey and feedback on the data collection exercise, helped us adapt the subsequent exercise of educational videos to promote engagement. Citizen scientists' participation in focus groups at the end of the project also helped us evaluate the project process and outcomes. After the project, about 2/3 of citizen participants felt they had contributed to scientific research.

The main barrier to engagement was the chosen IT platform which some citizen scientists could not access. For future citizen science projects, we suggest piloting several IT platforms to select the most suitable one, then during recruitment asking citizen scientists to confirm that they will be able to access the chosen platform.

Conclusions

Project outcomes indicate that citizen science can help improve citizen's knowledge and help them make informed decisions. Engagement and retention are key to success. This includes choosing the most suitable IT platform for communication. Offering incentives for focus group participation seemed relatively ineffective in this project.

Citizen scientists' knowledge about plant breeding methods increased during their participation in the project. Their trust in regulatory agencies did not appear to be influenced by this increase in knowledge.

Looking at transparency in the food supply chain and labelling of gene-edited fruits and vegetables, findings differed slightly between the follow-up survey and the focus groups. In the follow-up survey, citizen scientists disagreed that there is transparency in the food supply chain in terms of how fruits and vegetables are grown and agreed that gene-edited fruits and vegetables should be labelled. In the focus groups, however, there

was not any clear agreement regarding whether gene-edited fruits and vegetables should be labelled. This suggests a need for further in-depth qualitative research with citizens to explore the conditions under which they would support or not support labelling.

Background

Plant breeding has been practiced for millennia to produce genetically improved species; for example, to make precursors of today's well-known crops such as maize, wheat and apples more resistant to diseases, higher yielding, and more nutritious. Nevertheless, research shows that the majority of consumers do not know many aspects of food production including plant breeding (e.g., Lucht, 2015; Sutherland et al., 2020). This may lead to confusion and unwarranted scepticism among consumers regarding plant breeding, particularly novel plant breeding methods such as gene editing.

After EU Exit, the UK signalled its intention to diverge from some EU laws that require more regulation compared to many countries in the world. This divergence also included plant breeding, particularly use of biotechnology to improve environmental sustainability and stimulate innovation in plant breeding technologies (DEFRA, 2021a). Therefore, the Department for Food, Environment & Rural Affairs (DEFRA) conducted a public consultation exercise on the use of gene editing for crop and livestock breeding for an improved and more sustainable food system in the UK (DEFRA, 2021b). A Bill that defines some types of genome editing as 'precision bred organisms' (PBOs) completed its passage through both Houses of Parliament on 6th March 2023 and received Royal Assent on 23rd March 2023. Additionally, the European Commission published a study regarding the legal status of new breeding techniques under Union law (EC, 2021). The EC study confirmed that the current regulatory system applying the same legislation to new breeding techniques and genetically modified organisms involves implementation and enforcement challenges in the EU. Therefore, a follow-up study was recommended to explore the policy instruments that make the legislation more resilient, future-proof and uniformly applied. As a result, the European Commission adapted a new regulation on 5th July 2023 on plants produced by certain new genomic techniques to support the EU's Farm to Fork and Biodiversity strategies (EC, n.d.).

Gene editing is a laboratory technique that results in genetic changes equivalent to those used in traditional plant breeding. However, it is a more advanced technology than traditional breeding and genetic modification (where foreign DNA is added) resulting in controlled and targeted genetic changes in the host genome (Smyth et al., 2020; Zhang et al., 2017). Therefore, it has the potential to help producing abundant and healthy food with less negative impact on the environment, such as reduced carbon emissions due to less input in agricultural production (DEFRA, 2021b).

The implementation and continued use of novel food technologies depend in part, on public acceptance of the technology (e.g., Bearth & Siegrist, 2016; Frewer et al., 2011). Importantly, this acceptance often depends on factors not considered by technical risk assessments (Slovic, 1987). For instance, the impacts of emerging technologies are often unknown to the public, which can lead to fear and rejection of these technologies due to lack of familiarity. Although risk perceptions and benefit perceptions are important drivers of consumer acceptance of different food technologies, previous research suggest that knowledge, as well as perceived trust (e.g., in institutions and supply chains) and socio-demographic variables (e.g., gender, religion) influence public acceptance, either directly or indirectly via risk perceptions and benefit perceptions (Bearth & Siegrist, 2016; Kaptan, 2018). Recent research on future communication of genetic technologies recommends emphasising their tangible and relevant benefits (Bearth et al., 2022).

Improving citizens knowledge cannot be achieved by simply sharing subject-specific information on one occasion, but rather gradually with deliberative, participatory, and transparent approaches (Sutherland et al., 2020). Therefore, citizen science as an innovative participatory research method is a promising option, involving the public in dialogue and decision-making around issues related to risk and environmental threat (Bonney et al., 2016). In the context of making food policy, citizen science needs volunteers' active involvement in scientific research to benefit them (e.g., advancing their knowledge of plant breeding techniques), but also to benefit the research community and policy makers so they can make policy which is better informed and targeted (FSA, 2020).

Citizen science research consists of three approaches: Contributory, collaborative, and co-created. The contributory approach involves the public helping to collect data. The collaborative approach involves the public helping to adapt questions, analyse data, and disseminate findings. The co-created approach means the public can be involved in all stages of the scientific process (West & Pateman, 2016).

Aims and objectives

1. Improve citizens' knowledge of traditional and novel plant breeding methods.
2. Understand citizens' needs regarding a transparent food system that involves the implementation of novel technologies including gene editing.

Definition of citizen science

The Citizen science for food standards challenges programme required projects to be 'a collaboration between researchers, a specific group of citizens and, where appropriate, relevant partners from outside academia' and for citizens and partners to be involved in co-creating the projects. FSA and UKRI provided the following documents as a guide:

- ECSA ten principles of citizen science
- ECSA characteristics of citizen science
- FSA citizen science and food: a review

In this project, we applied both a contributory and collaborative citizen science methodology. Our contributory approach ensured that the project team designed the survey questions, and the citizen scientists collected data. Our collaborative approach enabled the citizen scientists to share their feedback regarding the pre-test survey questions and, therefore, help us to modify research design, findings of data analyses, and evaluation of project outcomes.

In addition, we applied citizen science in line with the ECSA's ten principles of citizen science (ECSA, 2015), and by considering ECSA's characteristics of citizen science (ECSA, 2020), and the recent FSA publication on citizen science and food: a review (FSA, 2020).

Regarding this project, Dr Gulbanu Kaptan published a blog post on how citizen science can benefit research in tackling societal problems and presented the results at two international conferences: The European Citizen Science Association Conference, Berlin, Germany, October 2022; and The Society for Risk Analysis Conference, Washington DC, USA, December 2023.

Methodology

Methods

The project started with an online survey that investigated citizen scientists' motivations for enrolling in the project, and their attitudes and knowledge regarding novel plant breeding techniques. The survey was conducted in April 2022, and was completed by 56 citizen scientists.

Following the survey, citizen scientists were asked to complete a data collection exercise to broaden their knowledge of traditional and novel plant breeding methods, as well as helping the project team examine citizen participants' needs and expectations regarding a transparent food system. They were asked to find the label "variety" on packed fresh fruits

or vegetables, search for the variety information on the web by accessing different links, and complete a 3-minute survey on Padlet about their findings, experiences and feedback. The participants' feedback demonstrated their positive engagement with the project and highlighted their unfamiliarity with plant breeding methods.

The feedback received regarding the data collection exercise suggested a need for an additional one to aid citizens' understanding of various breeding techniques and maintain the level of engagement. Therefore, the project team designed and applied a "drag and drop" exercise to match a list of plant breeding methods (e.g., gene editing, conventional breeding) to a list of crops with variety names (e.g., Sicilian rouge tomatoes, Star ruby grapefruit). The citizen scientists who completed this exercise were later given the correct answers.

The "drag and drop" exercise was followed by sharing two 10-minute videos and various online materials (e.g., podcasts, videos, articles) with citizen scientists over the Microsoft Teams platform. These materials aimed to provide information about traditional and novel plant breeding methods, their similarities and differences, and the regulatory framework. The videos and online materials were prepared and selected by a project team member with expertise on plant breeding and regulatory frameworks.

Next, citizen scientists were invited to complete a follow-up online survey with similar questions to the first survey, to assess changes in their knowledge and attitudes regarding the implementation of gene editing into the food system. This survey was completed by 30 participants in July 2022.

After completing each data collection exercise, citizen scientists were asked to share feedback over Microsoft Teams, and were encouraged to ask questions and make suggestions. Feedback on the data collection exercise was collected by Padlet. The citizen scientists sent questions, particularly about the learning resources, which we answered over Teams.

Finally, two focus groups were conducted. In total 12 citizen scientists evaluated the project in terms of the knowledge they gained and their experience of the process and provided feedback on how to more effectively conduct future citizen science projects. Participants also discussed issues such as how to ensure trust and transparency. The surveys, exercises, and focus groups took place between May and August 2023.

Recruitment

We recruited 69 volunteers via Leeds University Business School social media channels (i.e., LinkedIn and Twitter) and through the Business School's and Aberystwyth University's communications to their alumni residing in the UK and staff members. Potential participants were asked to complete a brief survey that asked their age, ethnicity, gender, and disability, in order to help recruit a diverse group of citizen scientists.

Ethics

The Ethics approval for this project (LTLBS-394) was obtained by University of Leeds School of Business, Environment and Social Services (AREA) Committee on 28th March 2022.

Alignment with citizen science principles

In line with Principle 1 of ECSA's 5 citizen science principles, the citizen scientists were actively involved in our research both as contributors and collaborators. They contributed to the project by collecting data for the core research team. They did this by checking the variety labels on packaged fruits and vegetables, and then searching information on the web about these labels to report their findings and experiences (e.g., how easy it was to find information, how helpful the information was). The data collection exercise helped the research team to understand what information were available on the web regarding variety labels and whether these were helpful to consumers. In the meantime, the exercise helped the citizen scientists to realise how (un)familiar they were about how fruits and vegetables were grown. The citizen scientists were also collaborators throughout the project by sharing their feedback and asking questions throughout the project, and by evaluating the project at the end through focus group discussions. In line with Principle 2, our project has scientific outcomes resulting from the citizens' responses to the two surveys, and their discussions in the focus groups.

In line with principle 3, both the project team and citizen scientists benefited from being involved in this project. The project was an opportunity for the researchers to obtain scientific outcomes that had the potential to feed into communications to the public and into policy making. The results of the project were disseminated in different platforms including a stakeholder workshop that was held in London on 26 January 2023 with businesses, regulatory agencies, policy makers, and academics, and a conference presentation in ECSA 2022 conference in Berlin (Germany). In addition, the citizen scientists reported that their knowledge about plant breeding methods and regulatory framework improved substantially.

In relation to Principle 4, the citizen scientists did not ask to participate in multiple stages of the project. This might have happened due to the technical difficulties we experienced with the virtual IT platform that was chosen for communicating with citizen scientists. Nevertheless, all project findings were shared with them timely and transparently. In addition, they were asked to provide feedback in accordance with Principle 5.

Research Findings

The project consisted of two online surveys (i.e. a survey at the start of the project and a follow-up survey on completion of learning activities), two exercises aiming data collection and engagement with the project, learning activities (e.g., short videos, podcasts) and two focus groups. Each of these followed by interacting with the citizen scientists over the Microsoft Teams platform about their feedback and questions. However, due to technical problems resulting from the IT platform, the interaction was limited than expected. The research findings about the two surveys and focus groups are provided below.

Citizens' prior knowledge and attitudes about plant breeding and the regulatory system

Participants were asked about their motivations for enrolling in the project, and their attitudes and knowledge regarding plant breeding techniques.

The top three motivations to enrol in our project were having interest in environmental and sustainability issues (84%), in healthy eating (80%), and willingness to learn more about how fruits and vegetables that they buy are grown (78%). Other motivations included willingness to understand more about the role of government in food labelling (66%), having an interest in plant science and technology (1%), and meeting with people of similar interests (26%).

More (23%) reported no knowledge of *how* fruits and vegetables are grown compared to having no knowledge of *where* they are grown (2%). However, very few (6%) thought it was not important to know where food is grown.

We assessed citizen scientists' understanding of plant breeding and familiarity with conventional and novel plant breeding methods with the following questions: "When you hear the term plant-breeding, what does it mean to you?" and "For the next items, we will present a term that is associated with plant-breeding. Please indicate how familiar you are with the following terms." The results to the question about plant breeding indicated that nearly all participants had correct understanding of plant breeding (e.g., "using selective breeding to create plants with certain desired attributes", improving and developing new varieties"). However, there were few participants with misunderstandings or incorrect beliefs (e.g., "genetically modifying plants to make them easier to grow and transport," "[plant breeding] sounds very artificial). About half responded to the question about their familiarity with the techniques that they were not familiar at all with conventional breeding methods such as mutation breeding (52%), and F1 Hybrids(40%), and a novel plant breeding method

Table 1. Citizen scientists' risk and benefit perceptions, trust, and their beliefs about transparency

Items	Disagree	Neither agree nor disagree	Agree
If I found out that a fruit or vegetable was grown by a new plant-breeding technology, it would feel less safe than food grown in a conventional way.	40%	31%	29%
If I found out that a fruit or vegetable was grown by a new a plant-breeding technology, I would be less likely to buy it.	42%	37%	21%
The benefits of new plant breeding technologies outweigh the potential risks.	10%	62%	29%
I trust UK regulatory agencies (e.g., FSA) to ensure that the fruits and vegetables which consumers buy is safe.	17%	23%	60%
The food supply chain (i.e., growers, importers, retailers, etc.) in the UK are transparent with respect to the country of origin for food that I buy.	27%	25%	48%
The food supply chain (i.e., growers, importers, retailers, etc.) in the UK are transparent with respect to how the food I buy is grown.	52%	31%	17%
Fruits and vegetables grown with new technologies should be labelled (opposed to that grown in conventional manner.	6%	23%	71%

CRISPR (54%). Additionally, 17% reported no familiarity at all with gene editing, compared to 100% who were somewhat or very familiar with genetic modification.

The findings on citizen scientists' risk and benefit perceptions, trust, and their beliefs about transparency are listed in Table 1. Survey participants did not have strong opinions about perceived risks of new plant breeding technologies (the first two items in Table 1), although the number of those who disagreed with the first two items was slightly higher than those who agreed and neither agreed or disagreed. In terms of benefits (Item 3), 62% neither agreed nor disagreed that benefits of new plant breeding technologies outweighs their risks suggesting not having enough knowledge on this. More than half (59%) trusted in regulatory agencies including the FSA to ensure that the food they buy is safe. Around half (52%) did not agree that the food supply chain in the UK is transparent with respect to how the food is grown. The majority (71%) agreed that fruits and vegetables grown with new technologies should be labelled.

Citizen's attitudes and knowledge about plant breeding and the regulatory system following their collaboration in the citizen science project

After the activity segment of the project, a follow-up survey was conducted online to assess citizen scientists' experiences with the project and their current level of knowledge about gene-editing. In comparison to the previous survey, they were asked more detailed questions about their perceived benefits and risks of gene-editing, as well as attitudes towards

Table 2. Citizen scientists' experiences with the project

Experience	Disagree/Strongly Disagree	Agree/Strongly Agree
Learned more about plant science	0%	94%
Learned about how fruits and vegetables were grown	0%	93%
Discovered something new about fruits/vegetables bought	7%	83%
Thought it was a fun activity	7%	67%
Understand more about government's role in labelling	17%	6%
Felt contributed to scientific research	10%	63%
Learned more about environmental/sustainability issues.	17%	57%
Learned more about scientific research	17%	53%

labelling preferences, trust in institutions, and the transparency in the food supply chain. Thirty (30) citizen scientists participated in the follow-up survey.

Experience with the project

The responses of the citizen scientists regarding the question about their experiences with the project are listed in Table 2. Overall, the citizen scientists had a positive experience by participating in the project. Nearly all (94%) reported that they learned more about plant science and how fruit and vegetables were grown. Additionally, 2/3 felt they contributed to scientific research, and over 50% felt that they learned more about how gene-editing may address environmental or sustainability issues.

Knowledge

In an open-ended question, we asked citizen scientists to briefly define, in their owns words, what terms like gene-editing and CRISPR meant to them. Of the individuals who completed this part of the survey (n=24), 23 participants were able to provide at least a partially accurate definition. Seven (7) responses highlighted that foreign DNA was not introduced into the host. In contrast, only 5 mentioned that there was some change or alteration in the DNA. Similarly, with respect to CRISPR, 16 participants correctly identified it as a technique, tool, or a method. Compared to the first survey conducted before the activity segment, fewer participants reported no knowledge of *how* fruits and vegetables are grown (4.2% vs 23%).

Perceived Risks and Benefits

Based on previous literature findings, we asked citizen participants to rate the extent to which they agreed or disagreed with several potential benefits and risks of gene editing.

Perceived Benefits

Participants agreed that there were numerous benefits for the adoption of gene editing technologies. There was unanimous agreement (100%) that gene-editing would speed up introduction of traits in plants with the potential to increase yields and develop more climate change resistant varieties. Additionally, most felt that gene-edited crops had the potential to reduce pesticide use (75%), food waste (67%) and land needed for agriculture (63%), and also to promote sustainability (65%).

Perceived Risks

The citizen scientists were also enquired about the degree to which they felt about potential risks of gene-editing. Over 2/3 (68%) disagreed that gene-editing seemed risky to individual health. There was concern about unknown long-term effects of gene-editing technologies (68%), however this was less regarding potential loss of diversity (44%) and not enough research being conducted (52%).

Comparing overall judgements of perceived risks and benefits, overall perceived benefits were greater than overall perceived risks. The more perceived benefits an individual felt towards gene-editing, the lower level of perceived risk they expressed.

Trust and Transparency

The majority of citizen scientists reported that they trusted (63%) in UK regulatory agencies (e.g., FSA) to ensure that the fruits and vegetables that consumers buy is safe, whereas only 17% did not trust these agencies. Only 42% believed that food supply chain is transparent with respect to country of origin. Moreover, only 21% believed that food supply chain transparent with respect to how food is bred or developed.

Labelling Preference and its Association with Perceived Risk

When asked, 79% of participants believed gene-edited foods should be labelled, in addition to a public registry of approved gene-edited foods. Overall perceived risk was strongly associated with preference for labelling. We also conducted a multiple regression analysis, regressing labelling preference on the individual perceived risk statements. Of these perceived risks, we found that concern over long-term unknown effects was the sole independent contributor to the variance in labelling preference.

Citizens' evaluation of the project

The citizen scientists' knowledge about both conventional and novel plant breeding methods improved during the project. They particularly found the videos prepared by the project team very helpful.

> "...it really clearly was laid out, this is breeding, these are the conventional methods, this is what gene editing is, this is why this isn't GMO"

The learning materials did not change some participants' previous views about genetic technologies, although they were found helpful.

> "I don't know if it changed my opinion too much on them [genetic technologies], but it definitely made me rethink a lot of things about that."

There was low consensus about labelling of gene-edited foods and a potential public register for transparency and openness of information (i.e., a public database that shows approved gene-edited foods).

> "Labelling showing that products have been subject to independent testing or Food Standards Assurance certification is a means to build confidence"
>
> "Regardless of whether you see GMOs or gene editing as a bad thing, you should at least be able to know whether your food has it or not"
>
> "Public register is fine, I don't think that's a big issue"
>
> "I don't have to go into a supermarket with a magnifying glass so that I can read everything on the labels and then have to go and do my own research as to what on earth it is that I'm being offered"

There was a consensus that companies with commercial interests should not communicate to the public. Instead, citizen scientists suggested alternative communicators such as the government, celebrities, and local initiatives.

> "I don't think that's going to be left to the manufacturers to be honest, I think definitely this should be a government thing"
>
> "People don't feel as pressurised to sit down and watch a documentary with David Attenborough for an hour. So I think that kind of way of engaging with people would be great"
>
> "...something like this citizen science project, on a bigger scale would be absolutely fantastic"

With respect to trust, the discussion was shorter compared to other issues listed above. The importance of a strong regulatory system to ensure trust was highlighted.

> "...the regulatory system needs to be strong enough to engender enough trust in the general public that this is safe for them to eat."

Reflections on Citizen Science

Our project was novel and successful to improve citizen scientists' knowledge on traditional and novel plant breeding methods and to have their voices heard by businesses, regulatory agencies, and policy makers about their needs and expectations in a transparent food system. To our knowledge, there are no other citizen science projects conducted either on this topic or that contributed to the successful implementation of a novel breeding technology to the food system. Thus, our results show that citizen science has great potential to be useful for policy making and resolving societal problems. There are also lessons learned in this project that could help future citizen science projects to achieve better. These lessons and our suggestions are outlined below, followed by how citizen scientists evaluated our project and their feedback.

1. *Establishing clear criteria for ethics approval process*. Because citizen science is a relatively novel approach, particularly in social sciences, the ethical review boards in the Universities may not be clear which criteria they should apply to ethics applications. This may result in long delays in the approval process. There is a need for the Universities to establish clear criteria for their Ethics committees regarding the approval of citizen science projects.

2. *Choosing a suitable platform for effective communication.* Effective communication between the research team and citizen scientists is an essential aspect of citizen science projects, particularly if there is any need for online communication. Therefore, we suggest testing different IT platforms and apps with small pilot groups before starting the project to prevent future technical problems and ensure effective communication. Even designing a specific app for the project may be worth considering depending available funding. In addition, during the recruitment process, potential participants may be asked to confirm that they would be able to communicate with the chosen IT platform.

3. *Maintaining engagement of citizen scientists*. As citizen scientists take part voluntarily, they are engaged individuals who are interested in the project. However, maintaining their engagement throughout the project can be challenging. Developing an engagement plan at the start of the project in collaboration with the citizen scientists, asking their feedback particularly on engagement throughout the project, creating and implementing short engagement exercises (e.g., finding the variety label and searching information on the web, in our case), not having many demanding tasks for the citizen scientists, and keeping the projects as short as possible may help researchers to maintain

engagement. In addition, having a project manager in the team to coordinate communication activities with citizen scientists, track their engagement, and take actions if there is a problem may be helpful to researchers interested in conducting citizen science projects.

Our project was evaluated by citizen scientists through focus group discussions. We sent an invitation to all citizen scientists over Teams and through email regarding focus groups that would be organised by the research team in August 2022 to evaluate the project. We conducted two focus groups with 12 citizen scientists, in total.

Nearly all focus group participants mentioned that they found the learning exercises, short videos prepared by our team, and the online materials shared very helpful to improve their knowledge about both traditional and novel plant breeding methods and the regulatory framework. For example, two participants expressed their views as follows:

> "...because there was active thinking involved in these exercises in terms of like, how am I thinking differently about this now that I've been educated on it compared to before? I think that definitely helped me realise a lot of things that I hadn't known first of all."
>
> "It was really beneficial for me to sort of – because I don't understand why the public don't understand, I don't understand why the news and everything, are using the wrong language and not communicating effectively. And it was just a really nice for me to understand, yes, this is what is needed, it's this sort of communication, not what the media are doing or whoever."

Based on their experiences with our project, the citizen scientists also made suggestions for future citizen science projects. The feedback indicates that in-person involvement and using apps (rather than video conferencing platforms) would be more engaging for the citizen science volunteers. For example, two participants expressed their views as:

> "If a similar citizen science project was run, have a sort of introductory in person session. It might not be as discussion based but just to put faces to names."
>
> "I know a few studies used apps before, for this project an app compared to Teams might be more useful because you can reach the information on your phone and then access while you are at the market or anywhere."

Conclusions and Implications

We aimed to improve citizens' knowledge of traditional and novel plant breeding methods through learning exercises. In addition, we aimed to understand citizens' needs regarding a transparent food system that involves the implementation of novel plant breeding technologies including gene editing.

We applied a contributory and collaborative approach by involving citizen scientists in data collection and enabling them to share their feedback and questions throughout the project, helping to modify the research design and evaluate the project.

We previously planned to use the data collected by citizen scientists as a basis to design a future database regarding gene-edited fruits and vegetables. However, as governments' plans were clarified about establishing a public register of precision-bred crop varieties to support transparency and openness of information, we were not able to use the collected data. On the other hand, the data collection exercise helped citizen scientists realise how (un)familiar they were with conventional breeding methods and the growing process of the fruits and vegetables, therefore boosting engagement with the project. This was a very positive outcome of the data collection exercise because previous research suggests that managing the participants' expectations and motivations in citizen science projects is a key factor in retaining them in the project (e.g., Encarnação & Morais, 2021).

As suggested in previous research (Cappa et al., 2020; Metcalfe et al., 2022), we provided feedback to participants after each task of the project and regular updates explaining at what stage we were and what was next. We did this to increase citizen scientists' attention towards the project and help them see the bigger picture.

Our contributory approach helped us to design and apply a second exercise for the citizen scientists to improve their knowledge about plant breeding methods and promote their engagement with the project. In addition, the educational videos that followed the exercises were prepared by taking into account citizen scientists responses to the online survey and their feedback about the data collection exercise. The focus groups that we conducted with some of the citizen scientists at the end of the projects helped us for the evaluation of the project in terms of citizen science and change in perceptions and beliefs about trust, transparency, and labelling.

The main limitation of the project that affected engagement negatively was the IT platform that was chosen to communicate with the citizen scientists. Due to a technical problem of the IT platform, some of the citizens informed us that they couldn't access to learning materials and

surveys provided over the platform. Regarding future projects, focus group participants suggested having alternative online communication methods such as Facebook. Therefore, the lower response rate to follow-up survey and to focus groups invitations may have resulted from the access issue of the IT platform. Asingizwe et al. (2020) concluded that participants' inability to use various technological infrastructure or their incapability to deal with different social platforms, make them less willing to engage in citizen science projects. For future citizen science projects, we suggest running a pilot test with alternative IT platforms and selecting the most suitable option. In addition, during the recruitment process potential citizen scientists can be informed about the IT platform that would be used and asked to confirm that they will be able to access to this platform.

To foster retention of the participants and have 30-40 citizen scientists in the focus groups, we offered financial compensation (£20/participant) as suggested by Cappa et al. (2018) regarding citizen science projects. However, we were only able to recruit 12 participants indicating that this level of financial incentivisation alone is insufficient for engagement and retention.

With regards to the project findings, the follow-up survey results indicated that citizen scientists' knowledge improved following the exercises and learning activities. For example, the survey results at the start of the project showed that about half of the citizens were not familiar with traditional plant breeding methods such as mutation breeding and F1 Hybrids, and novel plant breeding methods such as CRISPR. In the follow-up survey, however, most were able to provide some accurate information about these methods. In line with these findings, nearly all focus group participants highlighted that they found the exercises and learning activities very helpful to gain more knowledge about plant breeding techniques.

Both survey results demonstrated that more than half of the citizen participants trusted in regulatory agencies. This was also confirmed by some of the focus group participants by pointing out FSA as a trusted agency that should communicate gene-editing to the public.

Regarding transparency, nearly half of the citizens in both surveys disagreed that the food supply chain is transparent with respect to how the food is grown. In the focus groups, we wanted to explore the reasons of the negative opinion about transparency. The responses, mostly raised together with how foods are grown and labelling of gene-edited foods, indicated that the citizens' understanding of food supply chain transparency is uncertain. Therefore, we suggest that citizens' understanding of transparency and their needs regarding a transparent food system including implementation of gene editing need to be investigated further. Particularly, future research should examine how

citizens' mental models about growing processes of fruits and vegetables affect citizens' perceived transparency of the food system and their preferences for labelling of gene-edited fruits and vegetables.

With respect to labelling, a great majority of the citizens in both surveys agreed that fruits and vegetables produced with novel technologies should be labelled, even there was a public register for transparency and openness of information. The responses were slightly different in the focus groups because some of the participants mentioned that they may not require a labelling if gene-edited foods were tested by a trusted organisation and confirmed as safe to eat. Thus, labelling of precision bred foods should be further examined in future research, particularly through interview and focus groups to have a deeper understanding of public's willingness for labelling.

References

Asingizwe, Poortvliet, Koenraadt, van Vliet, Ingabire, Mutesa, & Leeuwis. (2020). Why (not) participate in citizen science? Motivational factors and barriers to participate in a citizen science program for malaria control in Rwanda. *PloS One*, *15*(8). https://doi.org/10.1371/journal.pone.0237396

Bearth, A., Kaptan, G., & Kessler, S. H. (2022). Genetically-modified and gene edited tomatoes: An experiment on people's perceptions and acceptance of food biotechnology in the UK and Switzerland. *Agriculture and Human Values*, *39*(3), 1117–1131. https://doi.org/10.1007/s10460-022-10311-8

Bearth, A., & Siegrist, M. (2016). Are risk or benefit perceptions more important for public acceptance of innovative food technologies: A meta-analysis. *Trends in Food Science and Technology*, *49*, 14–23. https://doi.org/10.1016/j.tifs.2016.01.003

Bonney, R., Philipps, T. B., Ballard, H. L., & Enck, J. W. (2016). Can citizen science enhance public understanding of science? *Public Understanding of Science*, *25*(1), 2–16. https://doi.org/10.1177/0963662515607406

Cappa, L., Laut, J., Porfiri, M., & Giustiniano, L. (2018). Bring them aboard: rewarding participation in technology-mediated citizen science projects. *Computers in Human Behavior*, *89*, 246–257. https://doi.org/10.1016/j.chb.2018.08.017

Cappa, Rosso, Giustiniano, & Porfiri. (2020). Nudging and citizen science: The effectiveness of feedback in energy-demand management. *Journal of Environmental Management*, *269*, p110759. https://doi.org/10.1016/j.jenvman.2020.110759

DEFRA. (2021a). *Gene Editing*. https://consult.defra.gov.uk/agri-food-chain-directorate/the-regulation-of-genetic-technologies/supporting_documents/Gene%20Editing%20Explainer.pdf

DEFRA. (2021b). *The regulation of genetic technologies*. https://consult.defra.gov.uk/agri-food-chain-directorate/the-regulation-of-genetic-technologies/

EC. (n.d.). *New techniques in biotechnology*. Retrieved 2023, from https://food.ec.europa.eu/plants/genetically-modified-organisms/new-techniques-biotechnology_en

EC. (2021). *Commission staff working document: Study on the status of new genomic techniques under Union law and in light of the Court of Justice ruling in Case C-528/16*. https://food.ec.europa.eu/system/files/2021-04/gmo_mod-bio_ngt_eu-study.pdf

Encarnação, T. & Morais. (2021). Citizen science and biological invasions: a review. *Frontiers in Environmental Science*, 303. https://doi.org/10.3389/fenvs.2020.602980

European Citizen Science Association. (2015). *Ten Principles of Citizen Science*. https://www.ecsa.ngo/10-principles/

European Citizen Science Association. (2020). *Characteristics of Citizen Science*. https://eu-citizen.science/resource/87

Food Standards Agency. (2020). *Citizen Science and Food: A Review*. https://www.food.gov.uk/research/behaviour-and-perception/citizen-science-and-food

Frewer, L. J. (2011). Consumer response to novel agri-food technologies: Implications for predicting consumer acceptance of emerging food technologies. *Trends Food Sci. Technol.*, *22*, 442–456. https://doi.org/10.1016/j.tifs.2011.05.005

Kaptan, G. (2018). Consumer Perceptions of Food-Related Risks and Benefits. In *Reference Module in Food Science*. Elsevier. https://doi.org/10.1016/B978-0-08-100596-5.21416-9

Lucht, J. M. (2015). Public Acceptance of Plant Biotechnology and GM crops. *Journal of Viruses*, *7*(8), 4254–4281. https://doi.org/10.3390/v7082819

Metcalfe, Kennedy, Mendez, & Muehlbauer. (2022). Applied citizen science in freshwater research. *Wiley Interdisciplinary Reviews: Water*, pe1578. https://doi.org/10.1002/wat2.1578

Slovic, P. (1987). Perceptions of risk. *Science*, *17*(236), 280–285. https://doi.org/10.1126/science.3563507

Smyth, J. S., Gleim, S., & Lubieniechi, S. (2020). Regulatory Barriers to Innovative Plant Breeding in Canada. *Frontiers in Genome Editing*, *2*, 11. https://doi.org/10.3389/fgeed.2020.591592

Sutherland, C., Sim, C., Gleim, S., & Smyth, J. S. (2020). Canadian Consumer Insights on Agriculture: Addressing the Knowledge-Gap. *Journal of Agricultural & Food Information*, *21*(1–2), 50–72. https://doi.org/10.1080/10496505.2020.1724114

West, S., & Pateman, R. (2016). Recruiting and Retaining Participants in Citizen Science: What Can Be Learned from the Volunteering Literature? *Citizen Science: Theory and Practice*, *1*(2), 15. https://doi.org/10.5334/cstp.8

Zhang, H., Zhang, J., Lang, Z., Botella, J. R., & Zhu, J. (2017). Genome Editing—Principles and Applications for Functional Genomics Research and Crop Improvement. *Critical Reviews in Plant Sciences*, *36*(4), 291–309. https://doi.org/10.1080/07352689.2017.1402989

Annex

Phase 1 Survey

We would like to thank you for agreeing to participate in our collaborative citizen science project. This project is designed to understand individuals' knowledge on plant breeding, and their expectations regarding a transparent food system involving novel plant breeding methods. As a first part of the project, we would like to ask you to complete a brief survey (about 5 minutes long) about your motivations for participating in this project, as well as your attitudes and knowledge about plant breeding techniques.

We thank you again for your interest in our project!

Have you ever participated in a "citizen science" project, where non-experts collaborate with scientists in their work?

Yes
No

If yes, how many such projects?

Please provide a few examples of such projects with which you have been involved, and the tasks you undertook?

We are interested in learning about the reasons for your participation in this citizen science project. There are no right or wrong answers; we are simply interested in what motivates you to take part in this study. Please rate how important each of the following reasons were for you to participate in this project:

Not important at all (1)
Not very important (2)
Somewhat Important (3)
Very important (4)
Extremely important (5)

I want to contribute to scientific research.
I am interested in healthy eating.
I would like to learn more about how the fruits and vegetables that I buy are grown. (3)

I feel like it will be a fun activity.
I want to learn more about how scientific research is conducted.
I have an interest in plant science and technology.
I have an interest in environmental & sustainability issues.
I want to understand more about the role of government in food labelling.
I want to participate in a citizen science project.

I want to learn how plant breeding impact my own health.
I want to learn more about the origins of the fruits and vegetables I buy.
I want to meet people with similar interests.
Other (Please specify)

How likely would you be to purchase a new variety of a fruit or vegetable that you normally buy (e.g., Pink Lady apple, Sable grape, etc.)?

Not likely at all
Not very likely
Somewhat likely
Very likely

Please rate your current knowledge about WHERE (i.e., country/region of origin) the fruits and vegetables you buy are grown:

No knowledge at all
I know where a few are grown
I know where some are grown
I know where all are grown

How important is it for you to know WHERE the fruits and vegetables that you buy are grown?

Not at all important
Not very important
Somewhat important
Important
Very important

How often do you base your food purchase decisions on WHERE food is grown?

Never
Rarely
Sometimes
Often
Always

Have you ever searched for information about WHERE the fruits and vegetables you buy are grown, beyond the information on a label?

Yes
No

If yes, how often have you done this?

Rarely
Sometimes
Frequently

How easy was it for you to find?

Very difficult
Difficult
Easy
Very Easy

Q6 Please rate your current knowledge about the process of HOW new varieties of fruits and vegetables are bred or developed:

No knowledge at all
I know how a few are grown
I know how some are grown
I know how most are grown

How important is it for you to know the process of HOW the fruits and vegetables that you buy are bred or developed?

Not all important
Not very important
Somewhat important
Important
Very important

Have you ever searched for information about the process of HOW the fruits and vegetables you buy are bred or developed, beyond information on the label?

Yes
No

How often have you done this?

Rarely
Sometimes
Frequently

Q8c How easy was it for you to find?

Very difficult
Difficult
Easy
Very easy

If you wanted to find information about how or where foods that you buy are grown, how likely would you go to each of these sources?

Not at all likely (1)
Not very likely (2)
Somewhat likely (3)
Very likely (4)

Family and friends
TV or radio programmes (e.g. cooking shows)
Government agency websites (e.g., Food Standards Agency, DEFRA and Department of Health
Food producers' websites
Newspaper/ News Website
Social media (Facebook/ Twitter, etc)
Food blogs

When you hear the term "plant-breeding", what does it mean to you?

For the next items, we will present a term that is associated with plant-breeding. Please indicate how familiar you are with the following terms:

Not at all (1)
Somewhat (2)
Very familiar (3)

Genetic modification (GM)
Gene-edited crops
CRISPR
Mutation breeding
F1 hybrids
Vertical farming
Robotic harvesting

To the best of your understanding, what is the relationship, if any, between the process of genetic modification (GM) and gene-editing? Please select one of the following:

There is no difference between the two methods
The two methods are partially related
The two methods are completely different
I am not sure if there is any difference

For the next items, please indicate the extent to which you agree or disagree with each of the following statements:

Strongly Disagree (1)
Disagree (2)
Neither Agree nor Disagree (3)
Agree (4)
Strongly Agree (5)

If I found out that a fruit or vegetable was grown by a new a plant-breeding technology, it would be less likely to buy it.
If I found out that a fruit or vegetable was grown by a new plant-breeding technology, it would feel less safe than food grown in a conventional way.
The benefits of new plant breeding technologies outweigh the potential risks.
I trust UK regulatory agencies (e.g., FSA) to ensure that the fruits and vegetables which consumers buy is safe.
Fruits and vegetables grown with new technologies should be labelled (opposed to that grown in conventional manner.
The food supply chain (i.e., growers, importers, retailers, etc.) in the UK are transparent with respect to the country of origin for food that I buy.
The food supply chain (i.e., growers, importers, retailers, etc.) in the UK are transparent with respect to how the food I buy is grown.

Phase 2 Survey

We would like to thank you for agreeing to participate in our collaborative citizen science project over the past weeks. As we come close to the end of the project, we would like to ask you to complete a brief post-survey (about 5 minutes long) about your experiences with this project, as well as your attitudes and knowledge about plant breeding techniques. We thank you again for your continued interest in our project!

First, we are interested in learning about your experience with this project. There are no right or wrong answers; we are simply interested in your thoughts about this study. Please rate the following statements:

Strongly disagree (1)
Disagree (2)
Neither Agree nor Disagree (3)
Agree (4)
Strongly agree (5)

I felt as if I contributed to scientific research.
I learned more about how fruits and vegetables are grown.
I thought it was a fun activity.
I learned more about how scientific research is conducted.
I learned more about plant science and technology.
I learned more about environmental & sustainability issues.
I now understand more about the role of government in food labelling.
I discovered something new about the origins of the fruits and vegetables I buy.

In the second part of this survey, we'd like to ask you about what you've learned about gene-editing and other plant breeding technologies.

For the next items, please briefly describe in a few sentences how you would explain the following terms. If you are unfamiliar with the term, please type “Not Sure”:

Gene-edited crops
CRISPR
Mutation breeding
F1 hybrids
Vertical farming
Robotic harvesting

To the best of your understanding, what is the relationship, if any, between the process of genetic modification (GM) and gene editing? Please select one of the following:

There is no difference between the two methods
The two methods are completely different
I am not sure if there is a difference

Next, we would now like to ask you about current feelings about plant breeding, the technology that is commonly used, and how it may impact your future decisions.

Please rate your current knowledge about WHERE the varieties of fruits and vegetables you buy are grown:

No knowledge at all
I know where a few are grown
I know where some are grown
I know where all are grown

How important is it for you to know WHERE the fruits and vegetables that you buy are grown?

Not at all important
Not very important
Somewhat important
Important
Very important

Since the beginning of the project, (not including the Variety Exercise), have you ever searched for information about WHERE the fruits and vegetables you buy are grown, beyond the information on a label?

Yes
No

How often have you done this?

Rarely
Sometimes
Frequently

Please rate your current knowledge about HOW new varieties of fruits and vegetables are developed (i.e., plant-breeding methods used):

No knowledge at all
I know how a few are grown
I know how some are grown
I know how most are grown

How important is it for you to know HOW the fruits and vegetables that you buy are developed (i.e., plant breeding methods)?

Not at all important
Not very important
Somewhat important
Important
Very important

Since the beginning of the project, have you ever searched for information about HOW the fruits and vegetables you buy are developed, beyond information on the label?

Yes
No

How often have you done this?

Rarely
Sometimes
Frequently

Please indicate the degree to which you feel the following are potential benefits of gene-editing:

Strongly Disagree (1)
Disagree (2)
Neither Agree nor Disagree (3)
Agree (4)
Strongly agree (5)

Gene editing speeds up the introduction of traits in plants, such as increasing yields or climate change resistance.
Gene editing reduces food waste.
Gene editing would result in lower pesticide use, and consequently environmental benefits.
Gene editing promotes sustainability.

Gene editing reduces the land needed for agriculture.
Gene editing promotes individual and public health
Gene editing results in crops cannot be distinguished genetically from conventional ones.

Q16 Please make an overall judgement for the degree of expected benefits that you feel the adoption of gene-editing in the UK will have:

No benefits at all
Moderate Benefits
Great Benefits

We would now like to ask you about your feelings about the potential risks of gene-editing:

Strongly disagree (1)
Disagree (2)
Neither Agree nor Disagree (3)
Agree (4)
Strongly agree (5)

If I found out that a variety of fruit or vegetable was bred/developed by gene editing technology, it would be less likely to buy it.
If I found out that a variety of fruit or vegetables was bred/developed by gene-editing technology, it would feel less safe than food bred in a conventional way.
Gene-editing technology seems risky to one's health
I am concerned that gene-editing would cause a loss of biodiversity.
I do not believe that enough research on the effects of gene-editing have been conducted yet.
The long-term effects of gene-editing are still unknown.

Please make an overall judgement for how risky you feel the adoption of gene-editing in the UK will be:

Not at all risky
Somewhat Risky
Extremely Risky

Finally, we would like to ask you some questions about your feelings towards regulatory agencies.

Strongly disagree (1)
Disagree (2)
Neither agree nor disagree (3)
Agree (4)
Strongly agree (5)

I trust UK regulatory agencies (e.g., FSA) to ensure that the fruits and vegetables that consumers buy are safe.
Consumers should be able to tell whether fruits and vegetables they buy were bred [or developed] using gene editing.
In addition to a public database of approved gene edited foods, there should also be a label on the pack or at the point of sale.
The food supply chain (i.e., growers, importers, retailers, etc.) in the UK is transparent with respect to the country of origin for food that I buy
The food supply chain (i.e., growers, importers, retailers, etc.) in the UK is transparent with respect to how the food I buy is bred/developed (i.e., plant breeding methods).

Q20 In the space below, we welcome any comments you might have about your experiences with this project. We thank you again for your time and effort!

Focus Group Guideline

Introduction

Part I: Improvement in knowledge about traditional and novel plant breeding methods

1. How has your knowledge about plant breeding, traditional and novel, methods improved throughout the project?

   a. PROMPT – What aspect has been most helpful in improving your knowledge?

   b. Are there still areas that are less clear?

   c. To what extent has this information on plant breeding methods and regulation been useful to you so far, or do you think it may be useful in the future?

Part II: Implementation of gene-editing into the UK food system: Trust and Transparency

1. What do you think needs to be done for the public to gain trust in the implementation of gene editing to plant breeding in the UK?

   a. PROMPTS - In your view, who should be responsible for building public trust – government, scientists, breeding companies, farmers, others?

2. What would give you more confidence about buying gene-edited food if they're on UK supermarkets' shelves?

   a. PROMPTS – are labels the way forward?

      - Would you be happy about accessing this information through a public register as proposed by the government rather than having this information on the label?

Part III: Citizens scientists' feedback about the project

3. What did you particularly like about the project – how did we, or did we not, meet your expectations?

4. What are your suggestions for involving citizens (our community) more in science projects?

Closure

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