Enhancing Participation Through Inquiry Learning and Citizen Science: Science for Everyone

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Abstract: Volunteers in citizen science projects contribute their labour to the activities of science, becoming involved in the advancement of science. With the advent of digital technologies, the involvement of non-scientists in scientific projects has mushroomed (see Curtis et al., 2018). However, the nature of the participation in citizen science has been limited in a variety of ways. We have adopted the term citizen inquiry to describe our approach. Our interest in inquiry learning was developed in the Personal Inquiry project (see Sharples et al., 2015) which developed an approach to supporting inquiries of personal relevance in science learning. We developed software to support pupils, our first iteration of the nQuire platform. Further projects explored ways in which such software could be of use in encouraging participation in citizen science inquiry. We designed the later iterations of the nQuire platform (nquire.org.uk) as a citizen science and inquiry learning tool, that can support any individual or organisation (with or without research background) to set up and manage their own scientific investigations. We report here on the impact of this work over a fifteen-year period. We discuss the ways in which this software has allowed enhanced participation in citizen projects and the potential development of this approach for democratising citizen science.

1 INTRODUCTION

We are interested in the development of science understanding and appreciation for the public. In contemporary society we need this understanding and appreciation for the public to become meaningfully involved in democratic decision making on issues of importance.

Often, we assume that the development of science understanding starts and is informed most of all by our formal instruction in science taking place in educational establishments. Those who thrive in such settings can potentially become professional scientists or find employment in jobs where knowing science is a prerequisite. But for many people, over a lifetime, their involvement in science continues by more informal means such as watching television programmes, reading popular science books, or becoming involved in amateur science clubs.

So, the science we learn in formal settings is only one part of the way we become interested and potentially involved and knowledgeable about science.

This paper describes work investigating the relationship between methods used to learn science at school and the development of our understanding of science through our appreciation and involvement in informal science activities. In particular, we have been working on citizen science to assess its potential to add particular informal learning opportunities to other more formal ways of learning science. The approach we have developed which informs all our work in this area is citizen inquiry. This is best summarized in this quote:

The term 'citizen inquiry' was coined to describe ways that members of the public can learn by initiating or joining shared inquiry-led scientific investigations (Sharples et al., 2013). It merges learning through scientific investigation with mass collaborative participation exemplified in citizen science activities, altering the relationship most people have with research from being passive recipients to becoming actively engaged' (Herodotou, Sharples and Scanlon, 2017, p 1).

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In this paper we describe how our work in citizen science, inquiry learning and the development of software to support participation has progressed over the past fifteen years.

2 CITIZEN SCIENCE

Acquisition of science knowledge is one part of the potential benefit for volunteers engaging in citizen science projects. By surveying participants in Zooniverse, one of the oldest online citizen science platforms, Masters et al. (2016) have established that volunteers are often picking up knowledge about science concepts depending on whether or not there was additional instructional material provided to them. They write:

'*more actively engaged participants perform better in a project-specific science knowledge quiz, even after controlling for their general science knowledge*' (Masters et al., 2016, p. 1).

However, Masters et al. and others have also described potential benefits from learning about the processes of science and have evidence that some citizen scientists believe they are learning also about the processes of science. Having been involved with other citizen science projects such as iSpot (Silvertown et al., 2014, Scanlon et al., 2014) and iNaturalist (Herodotou et al., 2023), we have developed an approach to the multifaceted ways in which we need to approach the evaluation of learning in citizen science projects.

We made attempts to investigate learning from involvement in using these platforms through the extraction of log files (such as number of projects joined, duration a volunteer is connected to the platform) both by reviewing the impact of involvement with the platforms and on the views of participants on what they have learned. An example of what can be learned by these mixed method approaches is given in Silvertown et al. (2014) writing about learning from iSpot.

'While we have anecdotal evidence from comments made by participants that they have learned, we do not have direct, quantitative evidence of learning in iSpot yet. However, we do know from a previous analysis of 400 participants' behaviour that they provided determinations for fewer than 40% of their very first observations, but that they themselves determined more than 60% of their 50th observations' (Scanlon et al., 2014, p142).

Our route into further work on promoting, developing, and evaluating involvement in citizen science occurred after a period of intensive work on the topic of supporting inquiry learning in formal settings. We will describe in the next section our attempts to develop inquiry learning approaches and more active participation in citizen science. Our approach has been developed by involvement in a number of funded projects over the last fifteen years.

These are summarised in Table 1.

Table 1: Funding for projects developing our approach.

Year	Funder	Project Title
2008-12	**ESRC/TELTRP**	**Personal Inquiry**
2012-13	**Wolfson**	**Open Science Lab**
2013-15	**Nominet**	**Young People's citizen science**
2017-21	**National Science Foundation**	**Learn CitSci**
2020-21	**Mental Health Scotland**	**Democratising research: a mental health pilot**
2020-21	**BBSRC**	**EDU Cit Sci**
2022-25	**EU Horizon**	**Extending Design Thinking Through Digital Technologies**

Our initial funding for work in schools for personal inquiry, led to investigations of inquiry learning in the Open Science Lab funded by Wolfson. This was further developed with students in a University technical college supported by Nominet. We developed our approach to evaluation of citizen science further during work with the National Science Foundation project, while experimenting with social missions funded partly by Mental Health Scotland. BBSRC provided support for development of a citizen science community, while funding from the EU is allowing us to test other features in a school setting.

3 INQUIRY LEARNING

We started this work in 2009 back at a time where ultramobile computing devices had first come into British schools and teachers were trying to work out what to do with them, particularly the possibilities

they offered of helping students work on projects that connected work in school and home and other settings in which they learn science. We received funding for a joint research councils funded project Personal Inquiry- *Personal Inquiry (PI): Designing for Evidence-Based Inquiry Learning across Formal and Informal Settings*, a research project funded in the first round of the ESRC/EPSRC Technology enhanced learning Programme. The aim of the project was to help children to develop scientific understanding using technology enhanced learning to support mobile and contextual learning. The project worked closely with a range of stakeholders including schools, discovery centres, and museums. In addition to hardware support, we realised that to develop the kind of software necessary to support the process of inquiry we had to instantiate it in a way that made sense both to teachers and to software developers, so we constructed a simple representation of the inquiry process (Scanlon et al., 2012). The new personalised learning approach we developed was important in the success of the project.

The reason we identified personal inquiry as a key theme for our work was because we were trying, as well as looking at the technological possibilities to support inquiry, to find ways of increasing motivation for students, around work particularly associated with the science curriculum. We thought there were three ways in which we could make school inquiries more personal. One was by focusing on oneself (Myself), one by focusing on work related to the community (My community) and one focusing on the local environment (My environment).

The project was successful, and this was demonstrated in the studies conducted in schools which indicate that the personal inquiry toolkit was successfully adopted in schools teaching science and geography by teachers and by pupils (aged 11 to 14). We worked in formal teacher directed lessons where students' work in classrooms was connected to field trips and homework sessions. We also worked in after school clubs. In this way we were able to establish that the toolkit *'effectively supported the transition between individual, group, and whole-class activities and supported learning across formal and informal settings'*. (Sharples et al., 2016, p. 309).

Towards the end of the project, we found ourselves working more with students outside the confines of the curriculum, outside the stated goals of their classroom work, working in after school clubs and in this context found that the software developed was still useful to support students. As a consequence, we decided to explore the potential for using and further developing this software support for informal settings.

3.1 Potential of Inquiry Learning Outside Formal Education

We received the next funding support to help us look at the potential for taking this approach to personal collaborative inquiry learning for schoolchildren in formal settings and broaden it to other members of the public in informal settings. In studies funded by Nominet (Herodotou et al. 2014, Sharples et al., 2017), we explored this which led to the public launch of a newly developed version of the software nQuire. (https://iet.open.ac.uk/projects/nquire-young-citizen-inquiry). Initial findings from the Nominet funded project and work from a PhD student (Aristeidou et al., 2017) on the exploration of methods for developing communities researching a topic of interest to them. These led us to conclude that there was potential for a fully functional platform to support work in citizen science, extending our approach. With financial support from the OU/BBC partnership (see below), a new version of nQuire was designed and launched (www.nquire.org.uk) that effectively supports community and citizen science activities.

Figure 1: The nQuire home page.

Volunteers can either take part in citizen science projects others created or design, pilot and manage their own citizen science activities. nQuire has been designed to the highest ethical and data protection standards and is free to use by the public (Herodotou et al., 2021). To enable design of high-quality studies, an authoring functionality for designing citizen science studies is in place. This is accompanied by a process of data quality review by experts.

3.2 Some Citizen Science Projects (or 'Missions') with nQuire

To give a brief summary of projects that we have done since our pivot towards citizen science we give a few examples. We have made the software available to anybody who wanted it, with our support, and we did

a few small scale inquiries, including one with the University of Wolverhampton where we were interested in views about novels, another Open University one on sleep chronotypes, one on observations of starling murmuration and another about the growth of trees. These were led by ourselves, and by others including Universities and Charities. While smaller scale than later inquiries these inquiries could become extended in time e.g., nQuire was used in capturing people's preferences of novels in a series of inquiries.

The platform is available to anyone to run their investigations. This includes members of our university, members of other Universities, other organisations or individuals wanting to research areas of personal interest.

After a few years of operation on a relatively small scale we attracted the attention of those who had worked on the development of Lab UK studies. These had been large scale studies where the BBC had partnered with scientists to collect data from the public on a range of topics related to broadcasts. After some conversations about the functionally of the platform we were approached by the BBC/OU partnership to consider whether the platform could work for investigations at large scale, the scale we might expect by connection with broadcasts. Up to this point the typical group of learners or citizen scientists that we had on an inquiry was around 200 participants, sometimes up to a thousand. In our partnership with the BBC/OU, we needed to plan an extension of the platform so that it could cope with hundreds of thousands of participants. The first example of this was the use of this new version of nQuire (named Tomorrow's world nQuire) to be deployed for future large-scale inquiries or 'missions'. We partnered with the British Trust for Ornithology to develop a set of inquiries as part of the BBC Gardenwatch campaign in 2019. The Gardenwatch investigation (or "mission") was designed by the British Trust of Ornithology and The Open University and promoted by the BBC Springwatch TV series. The purpose was to understand "who" lives in UK gardens by asking citizens to report on mammals, worms, and birds they observe in their gardens. More than 230,000 contributions were collected. Findings provided recommendations as to what people should be doing to support biodiversity in their gardens, for example, providing boxes and food to specific species. Another broader purpose was as an opportunity to include discussion of the inquiry in the TV programme and support and promote a call to action. If the mission allowed people to understand more about which resources are most important for the survival of species in gardens, this could encourage people to take action which would support biodiversity having found out more about how this all worked. For example, they might be encouraged to do more to support biodiversity in gardens by providing log piles, leaving grass, and feeding hedgehogs or similar approaches to using their gardens. nQuire currently hosts investigations in fields such as biodiversity mental health, literacy, and education.

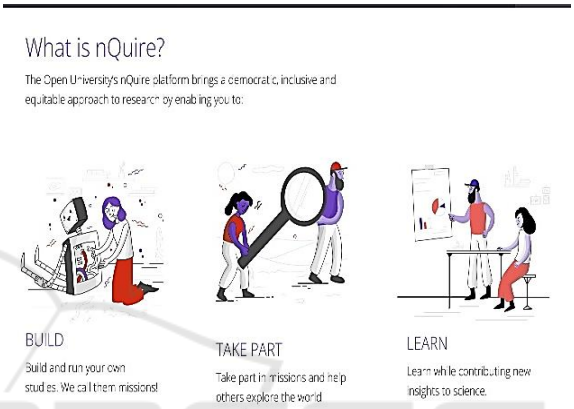

Figure 2: What is nQuire.

Stein et al. (2023) have reviewed multi-project citizen science platforms highlighting similarities and differences, which is helpful to see the range of options and functionalities.

The key difference with nQuire from other platforms available is our focus on supporting a range of different types of users and broadening the range of benefits for them. We would distinguish nQuire from other multi-project citizen science platforms as it is distinctive in the following ways: it enables **users** to define research questions, design a methodological approach and collect data, allow for community communications and commenting on data, integrated data analysis and visualisation tools, are accessible from a web browser and have supported authoring tools. These users can be members of the public not only scientists.

To summarise the ways in which our platform is designed:

- Enables design and management of projects through an authoring functionality.
- Data are securely stored in university servers.
- All citizen science studies have gained ethical approvals before going live.

- Data can be collected in a range of forms including text, image, sensors.
- Data can be confidential or open to the public to read, comment and like enabling peer learning.
- Dynamic data visualisations give immediate feedback to volunteers as to what emerging findings look like at a given point of time.
- Data can be shown on a map.
- Data can be downloaded at any time.
- Interim and final reports can be shared with participants.

We have conducted interviews and administered questionnaires to users of the nQuire platform who had chosen to participate in citizen science projects (Herodotou et al., 2017). We have done some work to understand what, whether and how people learn from participating in some of these citizen science inquiries. A questionnaire to 150 users of the platform revealed that main motivations for taking part in a mission were to contribute to scientific research, an appreciation of the importance of helping with research, their own personal interest, and curiosity about the topic (Herodotou et al., 2017). These results are both comforting and challenging. One challenge is represented by comments from users such as the desire for a number of activities to be completed before there was a sense of a developed trajectory of learning. (There are similarities here to the issue of tracking learners in formal settings to identify a trajectory of learning development). A view could be taken about whether participation in the platform had increased and individuals' knowledge and confidence and contributing to science and using scientific results. However, many of our participants have a limited participation on the platform, taking part in only one set of missions. In this regard nQuire is currently not as developed as platforms such as Zooniverse where the number of potential activities engaged in by participants is much larger. We do not expect all participants or volunteers to have a desire to create their own studies (and this is supported by our survey results), but we do hope that for some keen volunteers this will be a window to understanding and accessing science in ways their skills and knowledge are developed and citizen science activities are supporting not only science but also their local communities. We continue to explore the possibilities of tracking the learning outcomes of people who engage in our activities and extending our methods beyond reliance on self-support.

5 DEMOCRATIC PARTICIPATION IN CITIZEN SCIENCE

We have designed the nQuire platform (nquire.org.uk), as a citizen science and inquiry learning tool, that can support any individual or organisation (with or without research background) to set up and manage their own scientific investigations in any research field (Herodotou, Sharples, Scanlon, 2017). In this regard we are mindful of the principles of citizen science outlined in this document by the European Citizen Science Association (ECSA) (https://osf.io/xpr2n/wiki/home/) and enthusiastic about the idea of opening science to all including those with no relevant qualifications or expertise.

We consider citizen science to be a means through which people can educate themselves. It is potentially a means to provide support for them in developing life-long skills, in particular critical and scientific thinking. These are much needed to understand and cope with pressing socio-scientific issues. Offering people opportunities to understand and engage with science (broadly defined to include natural, physical, and social science) in ways that are responsive to their own needs, could develop trust in the outcomes of research and help people make decisions in an informed and evidence-based manner reducing, for example, the risk of trusting misinformation.

Our ambition therefore in this work is to open the knowledge production process to a wider group in society using the citizen science inquiry method. That is our ambition is to use this to increase the knowledge of how science and research is done in the general public so that people can understand how science is produced and as a result build greater trust in scientific outcomes and potentially be more aware of contentious claims.

We are investigating how can this be achieved through enabling people to design their own investigations and to receive training as to how to design a good scientific study in order to make a start on democratising current scientific practices. This is an ambitious project. Offering training to scientists on how to engage with their participants in ways that benefits result for the science, scientists and citizens involved. We also see such work as potentially helping to democratise current scientific practices by offering training to scientists as to how to engage with their participants in ways that benefit both the science and citizens, and by designing tools that scaffold the process of opening science to the public (visualisations etc).

Like (Bela et al., 2016) we would like to make progress in operationalising the transformative aspirations of citizen inquiry to support the development of scientific thinking skills in the general population.

6 CONCLUSION AND FUTURE PLANS

As a consequence of 15 years of development we now have a pedagogically informed platform for citizen science which allows us to consider learning at scale. nQuire is our pedagogically informed citizen science platform. It has been developed by The Open University to support individuals and organisations design, launch, and manage scalable research projects. We can support large-scale online investigations in any topic or discipline, and currently we have recorded more than a quarter of a million contributions to missions.

Individuals or organisations can use our authoring environment to create scientifically robust and ethical investigations. For scientists and others wishing to use the platform there is an overhead associated with authoring and taking the appropriate steps for ethical approval. This is monitored by the nQuire team but so far, the process is reasonably smooth.

To realise our ambitions, we will continue to extend and develop the platform. So far, we have developed appropriate tools to put in place to support our ambition. We think that integrating activities with our citizen inquiry missions will give us the opportunity to further test this approach. We will work to further understand the aspirations of our users. As more inquiries or missions are developed this will help us test out the proposition of what we need to do to further democratise research.

However, our most recent funded work with the nQuire platform is taking us back to the original inspiration of this work, inquiry learning in schools. nQuire is one of the emerging technologies being explored to encourage and facilitate the development of design thinking in schools. This design-based research funded by the EU Horizon programme and Innovate UK (Exten(DT)^2, http://www.extendt2.eu).

This project involves us in working with eight partners throughout Europe on exploratory case studies with emerging technologies in schools. Our contribution to the project is the development of a version of nQuire, *nQuire for students*, that can be used to develop students' research skills in primary and secondary schools.

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