A design-based study of Citizen Inquiry for geology

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Abstract. Citizen Inquiry forms a new method of informal science learning and aims to enable the engagement of citizens in online scientific investigations. Citizen Inquiry combines aspects from Citizen Science and Inquiry-based learning and is implemented through a community of practice where people having a shared interest interact and exchange knowledge and methods supported and guided by online systems and tools within a web-based inquiry environment. To explore the potential of Citizen Inquiry, a series of design-based studies will be developed to help in understanding and improving the engagement of citizens in online scientific investigation. "Inquiring Rock Hunters" is the first design-study of Citizen Inquiry, applied to Geology, and it explores the experience of participants with inquiries, other participants and tools.

Keywords: Citizen Inquiry, Online Science Education, Citizen Science, Inquiry-based Learning, Geology

1 Introduction

The aim of the research project is to support members of the public in designing and engaging in practical science investigations through online communities of interest. Today, citizens are required more than ever before to make decisions concerning scientific issues that influence their personal lives. The involvement of citizens in public decision making has always been an obligation which is now even more vital in addressing problems of common concern [1]. Citizens have to adopt a sense of shared responsibility for issues regarding their communities or the world and become active during the change process. Issues such as health care or energy policy are linked directly to the well-being of the community and hence our personal lives.

According to the "Public Attitudes to Science" report [2], while citizens recognise personal benefits from involvement in science, the largest proportion (56%) of the citizens in the U.K. say they do not feel informed about science. In addition, a smaller but significant percentage (32%) of citizens report that they do not feel clever enough to understand science and technology and 15% do not understand the point of all the science being done today. It is this lack of scientific literacy and involvement in science that forms the focus of the present research.

2 Background

To address the problem of the lack of scientific literacy, the National Research Council [3] proposed changes to science teaching to engage learners in authentic inquiry and research. Inquiry-based learning (IBL) has been proposed as the best path to achieve scientific literacy because it provides learners with the opportunity to discuss and debate scientific ideas [4]. Moreover, IBL involves a departure from content-aware learning while enhanceing the engagement of learners in the processes of science by giving them the opportunity to pose questions, generate and analyse data, draw conclusions, and communicate findings [5]. Informal science education programs [6] as well as authentic inquiry practices and science outside of the classroom can provide one of the venues for the scientific inquiry to be explored. An example of this orchestration is the Personal Inquiry project [7].

The Public Engagement with Science (PES) "dialogue" or "participation" model [1], developed in the last 14 years, aims to change personal science understanding, the role of the individual person within a community, and the relation between science and the society. An important component of PES is to bring together science experts and non-experts in discussions to improve understanding of issues and to engage them in shared scientific activities. Public Participation in Scientific Research (PPSR) is another public-science model in which adults and children take part in the various aspects of scientific enterprise [1]. Citizen Science projects are included in PPSR and are defined as "Projects in which volunteers partner with scientists to answer real-world questions" [8]. The main aim of a Citizen Science project is to produce more science and it is usually directed by scientists. In some cases citizens are only considered by scientists as a way to monitor and gather data [9] or as a means for the scientists to increase their research productivity by the computational or intellectual power of citizen volunteers [10]. In these cases the citizen scientists participate in a small part of the overall process, usually the data collection (e.g. iSpot) or the data classification (e.g. Galaxy Zoo). Only a few projects involve Citizens in all the stages of the research (e.g. Sherman's Creek Conservation Association).

Citizen Science can also be considered a powerful tool for public education as it contributes to the advancement of scientific literacy, informs about specific sciences, enlightens the scientific method, and it brings new voices to scientific research [11]. Citizen Science generates important informal learning experiences through its engagement with several aspects of authentic science [12]. Inquiry experiences can provide valuable opportunities for public to improve their understanding of both science content and scientific practices [13] and Citizen Science makes them available. However, in order for citizen science to be educationally beneficial a number of key factors have been identified.

Jordan et al. [12] note the need for balance between learning goals and scientific goals in a Citizen Science project. Thus, there must be a balance in the data collection to be achieved and the expected broad learning goals. The evaluation plan should ensure that the learning goals are consistent with the project activities, the learning outcomes are presented with clarity and both of them can be measured through indicators [14]. Pandya [15] also suggests that the most successful projects will involve

community members as active participants in every aspect of the scientific procedure. That will happen by co-managing the project (involving community leaders, interactions between scientists and citizens and providing training to the members), engaging the community at every step including entire families, incorporating multiple kinds of knowledge and disseminating findings shared to all the participants. Yet, people of all ages need support to act as scientists, by carrying out appropriate investigations, collecting and examining authentic data and presenting their results in a systematic manner [16].

3 Citizen Inquiry

Citizen Inquiry forms a new method of online science learning and combines aspects from Citizen Science and Inquiry-based learning, producing science learning experiences within distributed communities of interest. Important components of such an orchestration are collaboration, knowledge sharing and peer review (Citizen Science) as well as experimentation, discovery, critique and reflection (Inquiry-based Learning). At the same time, Citizen Inquiry applies to adult learners who no longer participate in formal education [17], [18], [19], [6] and includes personal meaning making activities. Citizen Inquiry may fill the gap between Citizen Science and Inquiry-based learning and lead to a novel way of public engagement in science.

Citizen inquiry is proposed as a new method of learning, which will enable the engagement of citizens in online scientific inquiries. Regarding the level of public engagement, it falls closer to the co-created projects [20] and to this end, the participants of Citizen Inquiry projects will be expected not only to be active during the whole project but also to improve their understanding of science and develop skills used by scientists.

Moreover, Citizen Inquiry emerges as an informal learning mechanism as it is developed outside the formal education's curricula and is being driven by the personal interest of citizens employing their everyday experience with science and its underpinning reasoning. Similar to Inquiry-based Learning, it engages citizens with scientific activities such as collecting data, conducting experiments and reflecting on their work [21], [22]. By extension, Citizen Inquiry involves citizens in planning and implementing their own inquiries in a self-directed way, employing scientific tools and skills, sparked by their personal experience of everyday science. Citizen Inquiry would be implemented through a community of practice where people (experts and beginners) having a shared interest will interact and exchange knowledge and methods supported and guided by online systems and tools within a web-based inquiry environment.

4 Research Question

This research will focus onthosescience fields where expert and non-expert scientists caninteract in an online community of practice in order to exchange knowledge and methods of experimentation through peer collaboration and mentoring. The outcomes

of the research will help in understanding and improving public engagement with science and facilitate the design of Citizen Inquiry. Within this frame of reference, the research question formed at this stage is:
"How can non-expert scientists engage in successful online inquiry based learning through peer collaboration and mentoring by experts without formal instruction?"

Focusing on its main components, the question is then split into four sub-questions/categories:

1. *Inquiry-based Learning*: How do non-expert scientists engage with the phases of the inquiry process?
2. *Collaboration*: In what ways do the participantscollaborate: which tools do they prefer to use and how do they interact?
3. *Mentoring*: What help do non-expert scientists requestand how do they make use of that help?
4. *Informal settings*: How effective is the web-based inquiry environment in supporting engagement in scientific investigation?

5 Research Methodology

The current study employs a design-based research method. Designed-based research utilizes mixed methods during the iterative research in order to analyse the outcomes and re-design the intervention [23], [24]. Hence, it is a methodology comprised of both qualitative and quantitative research applied to the research needs. The combination of these increases the "objectivity, validity, credibility and applicability" of the findings [25].

The current methodology is considered sustainable for this research as it focuses on the "development of sustained innovation in education" (p. 251) [24] and therefore it acknowledges the enabling contributions of technology to education and the call for understanding its connection with learning.Design-based research in this study analyses and develops the interactions of participants with the technology, the activities and the other participants. Each design study will build on the knowledge gained from initially the pilot study (first design-study) and then a series of design-based studies over the next 2 years of my doctoral studies. The results will help in understanding the engagement of citizens in online scientific investigation and then improving it by informing the design of the pedagogy and technology accordingly.

The research questions will apply to each of the forthcoming design-studies. It is expected that the question-framework mentioned above will be revised and modified to fulfil the specific aim of each design-study. The evaluation of the studies employs both qualitative and quantitative analysis techniques and includes:

- Interviews and focus group discussions with the individual participants involved in the design-studies to assess engagement with the process and technology and the attitudes to Citizen Inquiry.
- Processing of the scientific investigations and other scientific related data produced.

- Collecting and analysing online communication, interaction and engagement with the other participants.
- Surveying participants for the effectiveness, desirability and usability of the online platform.

6 Citizen Inquiry on Geology: "Inquiring Rock Hunters" project

The first design-study of Citizen Inquiry applies to Geology and focuses on engagement by amateur geologists in online scientific investigation through collaboration with other amateurs and mentoring by expert geologists. The "Inquiring Rock Hunters" project lasted for a month and exemplified Citizen Inquiry by enabling adult citizens to run their own investigations in geology and giving them the opportunity to collaborate with scientists. The interaction of the citizens with the scientific investigation and the scientists took place on an online platform called nQuire[26] which supports the social nature of Citizen Inquiry and provides tools to support both the investigation and the communication between the participants. The 25 participants of Citizen Inquiry were expected not only to be active during the whole project but also to improve their understanding of science and develop skills used by expert geologists.The evaluation methods of this first design-study include online questionnaires, online and face-to-face interviews and online focus groups discussions seeking to explore the experience of the participants with the inquiries, the other participants and the tools. The data analysis will follow a top-down approach, driven by the research objectives. The outcomes of this study will then inform the design of the next intervention.

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