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Citizen Inquiry: Engaging Citizens in Online Communities of Scientific Inquiries

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Abstract

Citizen Inquiry has been proposed as an informal science learning approach to enable widespread involvement in science and empower citizens with reasoning and problem-solving skills used by scientists. It combines aspects from citizen science and inquiry-based learning, producing science learning experiences within distributed communities of interest. A central challenge for Citizen Inquiry is to involve citizens in planning and implementing their own investigations, supported and guided by online systems and tools within an inquiry environment, while collaborating with science experts and non-experts.

This thesis explores how to create an active and sustainable online community for citizens to engage in scientific investigations. To this end, it investigates the design of online communities, recruitment and retaining of members, factors that engage or disengage members from the community, and whether and how members learn throughout their participation. The intervention comprises two iterations of Citizen Inquiry communities: 'Inquiring Rock Hunters' and 'Weather-it'. The communities were accommodated by the nQuire platform and the nQuire-it toolkit, respectively, software designed and structured to support collaborative personally-meaningful inquiry learning.

The findings of this research are explained through an analysis that compared the two design studies with previous research on citizen participation projects and online communities. Results highlight the importance of frequent project communication, multiple ways of participation, software usability, and interaction and collaboration between the members, while indicating disengagement factors such as lack of time, interest and confidence. Different categories of learning are identified (activity, on-topic and community), emphasizing the understanding of inquiry activities as part of a complete scientific process and the balance between fun and

learning. The thesis concludes with design considerations for the creation of future Citizen Inquiry and other citizen participation communities.

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Chapter 1: Introduction

1.1 Introduction

This PhD thesis investigates how citizens engage with online scientific investigations. It explores the creation and maintenance of online Citizen Inquiry communities that involve people in creating and participating in collaborative inquiries. This chapter describes the background and motivation for this thesis, along with a synopsis of the related research, a summary of the contributions to the field of public participation in scientific research (PPSR) and online communities, and an outline of each of the chapters in this thesis.

1.2 Motivation and Background

Surveys on public attitudes to science (Ipsos MORI, 2011, 2014) reveal that despite the fact that citizens recognise the benefits from involvement in science and technology, they experience difficulties in gaining information and developing understanding. It is this lack of scientific literacy that motivated the focus of the present research. The involvement of citizens in public decision making has always been an obligation, but now is even more vital in addressing problems of common concern (McCallie et al., 2009). Citizens are required to adopt a sense of shared responsibility for issues regarding their communities, or furthermore the world, and become active during the change process as this is linked directly to the well-being of the community and hence their personal lives.

The PPSR inquiry group focuses on exploiting citizen science to boost public participation in science (McCallie et al., 2009) by involving citizens in authentic scientific inquiry; that which scientists conduct in everyday practice (Roth, 2012). PPSR projects involve citizens in research endeavours whilst collaborating with science experts to answer real-world questions. Although there is increasing interest in informal science education (Lloyd et al., 2012), the scientific goals in citizen science projects prevail over the learning goals. It is argued that citizens in citizen science

are being used by scientists (Stodden, 2010), they are a cheap way for data collection and analysis (Alabri & Hunter, 2010; Conrad & Hilchey, 2011). Thereby, strategies for improving citizens' engagement and evaluation of projects' results focus mainly on the scientific outcomes for the researchers, whilst from an educational perspective, little research has been yet undertaken (Edwards, 2014).

Inquiry-based learning (IBL) has been acknowledged by the American Association for the Advancement of Science (2008) as a good way to achieve scientific literacy as it engages people in the process of science. Thus, learners pose questions, generate and analyse data, draw conclusions, debate and discuss scientific ideas and communicate their findings (Oberhauser & LeBuhn, 2012). Yet, citizens of all ages need guidance to engage in the inquiry process and act as scientists (de Jong, 2014); IBL is a school-based science learning model that requires a teacher to coordinate the learning.

Citizen Inquiry is proposed as an informal learning approach that combines components from citizen science and IBL (Aristeidou, Scanlon & Sharples, 2013; Sharples et al., 2013). The aim of Citizen Inquiry is to produce learning experiences within distributed communities of interest and empower citizens with skills used by scientists. Thus, it supports citizens in planning and implementing their own personally meaningful investigations in collaboration with science experts and non-experts. This perspective of personal inquiries that reflect the everyday life activities is argued to enhance the reflection of citizens about the nature of science and scientific inquiry (Schwartz, Lederman & Crawford, 2004), engage learners with even unexciting data (Woodgate et al., 2008) and place them at the centre of authentic scientific inquiry instead of the "periphery of authentic contexts" (Schwartz et al., 2004).

Citizen Inquiry, unlike many citizen science projects, engages citizens in all the stages of the scientific process and its main focus is on learning about the scientific process. Inquiry-led environments consisting of online systems and tools provide appropriate guidance during each inquiry step; the demonstration of science content in the context of scientific methods has been

suggested as a way to improve science in previous studies on PPSR projects (Cronje et al., 2010; Crall et al., 2012).

However, opening up the scientific process to distributed communities of citizens is still at an early stage, raising questions about how citizens can engage in this challenge of Citizen Inquiry? The creation of online Citizen Inquiry communities allows study of the engagement of citizens with scientific investigation. The different stages of the lifecycle (Wenger, McDermott & Snyder, 2002) of an online community have been examined to facilitate the creation and monitoring of the community and provide approaches and strategies for each stage. Furthermore, research on user engagement and motivation in PPSR and other online communities is reviewed to provide insight into the methods of researching citizen engagement.

1.3 Research Aim and Questions

This PhD thesis employs a design-based research approach (DBRC, 2003) and it is structured into two design studies (Figure 1).

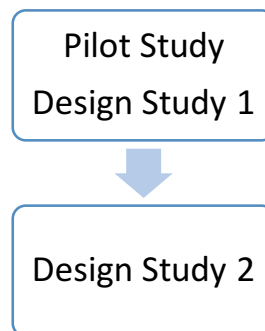


Figure 1: Design-based research approach – structure

The initial intervention, ‘Design Study 1’, was developed around the ‘Inquiring Rock Hunters’ community with the aim of understanding the engagement of citizens in scientific investigations and provide guidelines to facilitate the next design of a Citizen Inquiry project. Design Study 1 went through a pilot phase before its launch. The research question formed at this initial stage is:

(i) *“How can citizens engage in inquiry-based learning through peer collaboration and mentoring by experts without formal instruction?”*

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

1. Motivation: What motivated people to take part?
2. Inquiry-based learning: How do participants engage with the inquiry process and learning?
3. Collaboration: In what ways do the participants collaborate: which tools do they prefer to use and how do they interact?
4. Mentoring: What help do non-experts need and how do they make use of that help?
5. Inquiry-led environment: How effective is the web-based inquiry environment in supporting engagement?
6. Experience: What kind of experience do people gain from taking part?

A second more extended intervention 'Design Study 2' was developed around the 'Weather-it' community. The outcomes of Design Study 1 highlighted the need for an improved sense of community and sustaining of the engagement levels. As a result, the main research question is re-formed to include objectives around the creation, activity and sustainability of online communities (RQ1) and the impact of investigation ownership on the level of engagement (RQ2). The engagement of citizens with the inquiry process remains part of the research question (RQ3).

(ii) "How can we create an active and sustainable online community for citizens to engage with online scientific investigations?"

The following sub-questions facilitate the exploration of the main research question:

RQ1: How can we create an active and sustainable online community for Citizen Inquiry?

RQ2: How can Citizen Inquiry engage members of the general public with investigations?

RQ3: How can Citizen Inquiry participants adopt an inquiry process that follows good practices of science learning?

1.4 PhD Thesis Contribution and Novelty

This thesis offers the following contributions to citizen participation in scientific research and online communities:

- A review of the typologies of PPSR and the informal learning that takes place within these projects.
- A review of the theory and practice of online communities; the lifecycle of online communities from the initial idea to the transformation and user engagement and motivation practices within these communities.
- An extensible scheme with approaches and research methods for creating, sustaining and evaluating the community creation, engagement and science learning.
- The development of design considerations for the creation of future Citizen Inquiry and other similar online communities.

The innovative nature of this PhD research lies in the following:

- The citizens participating in the Citizen Inquiry communities of this research are not limited to collecting and analysing data as in most of the PPSR projects. On the contrary, they are guided to get involved in all of the inquiry phases of the scientific investigation.
- The design of the two studies was focusing on supporting and improving the learning outcomes and not only the scientific outcomes as in other PPSR projects. Thus, science learning does not happen as a side effect of citizen participation in the project; instead, it is the result of targeted design for learning.
- The participants of the Citizen Inquiry communities are given the opportunity to investigate personally meaningful science and thus, create and conduct their own investigations based on their everyday science experience. This has led to the development of citizen-led communities of scientific investigations where citizens are not placed in the periphery of authentic scientific inquiry but in the centre, acting as scientists.

- This PhD research employed the collection and analysis of both qualitative and quantitative data, providing a better picture of the participation and learning within the community and improving the interpretation of the data.

This thesis has also contributed to the field with the following publications. Substantial parts in Chapter 4 and Sections 5.3.4, 6.3, 6.5.1, 6.5.2 and 6.5.3.1 draw in part from the published papers and reports:

- Aristeidou, M., Scanlon, E., & Sharples, M. (2013). A design-based study of Citizen Inquiry for geology. In K. Maillet & T. Klobucar (Eds.), *Proceedings of the Doctoral Consortium at the European Conference on Technology Enhanced Learning co-located with the EC-TEL 2013 conference* (pp. 7-13). Paphos, Cyprus: CEUR.
- Aristeidou, M., Scanlon, E., & Sharples, M. (2014a). Inquiring Rock Hunters. In C. Rensing, S. de Freitas, T. Ley & P. J. Muñoz-Merino (Eds.), *Open Learning and Teaching in Educational Communities, Proceedings of the 9th European Conference on Technology Enhanced Learning, EC-TEL 2014* (pp. 546-547). Graz, Austria: Springer International Publishing.
- Aristeidou, M., Scanlon, E., & Sharples, M. (2014b). *Inquiring Rock Hunters* (Pilot Study Report). doi:10.13140/RG.2.1.4975.4323
- Aristeidou, M., Scanlon, E., & Sharples, M. (2015). Weather-it: Evolution of an Online Community for Citizen Inquiry. In S. Lindstaedt, T. Ley & H. Sack (Eds.), *Proceedings of the 15th International Conference on Knowledge Technologies and Data-driven Business, i-KNOW 2015*, article 13. Graz, Austria: ACM.
- Aristeidou, M., Scanlon, E., & Sharples, M. (2015). Weather-it missions: A social network analysis perspective of an online citizen inquiry community. In G. Conole, T. Klobučar, C. Rensing, J. Konert & E. Lavoué (Eds.), *Design for Teaching and Learning in a Networked World, Proceedings of 10th European Conference on Technology Enhanced Learning, EC-TEL 2015* (pp. 3-16). Toledo, Spain: Springer International Publishing.

- Sharples, M., Aristeidou, M., Villasclaras-Fernández, E., Herodotou, C., & Scanlon, E. (2015). Sense-it: A Smartphone Toolkit for Citizen Inquiry Learning. In Brown, T. H., & van der Merwe, H. J. (Eds.), *The Mobile Learning Voyage – From Small Ripples to Massive Open Waters, 14th World Conference on Mobile and Contextual Learning, mLearn 2015* (pp. 366–377). Venice, Italy: Springer International Publishing.

1.5 Thesis outline

Chapter Two presents a survey of the literature and places the current research within the context of previous and related work. It identifies models and typologies of projects for PPSR, according to their activities, types of participation and goals. Then, it evaluates the informal learning that takes place in these projects, leading to the introduction of Citizen Inquiry and its orchestration. The review also includes literature focusing on the creation and sustainability of citizen participation and other online communities. User engagement and motivation are further examined in order to support the design of online communities of Citizen Inquiry and improve the existing engagement methods and outcomes.

Chapter Three describes the research methods used in this research. It discusses design-based research and mixed-methods research. Then, it covers the design methods for the two interventions, the ethical considerations behind the design, data collection techniques, methods of data process and analysis, and outcomes evaluation.

Chapter Four covers the design and settings of the first intervention (and its pilot study), which was developed around ‘Inquiring Rock Hunters’, a Citizen Inquiry community for rock investigations. It describes the exploration of relevant projects, the description of the hosting platform, the project preparation, the trial study, and an overview of the study results. The main findings indicate the lack of follow-up discussions and interaction between the participants. The chapter concludes with design considerations for the next intervention.

Chapter Five presents the preparation for the second intervention, which was developed around ‘Weather-it’, a community for weather investigations. As the design of this study focuses on the

creation of a sustainable online community, based on feedback from the first intervention, existing work in the field of online communities and social networks is reviewed. Then, the requirements and needs for the online community are outlined in categories, according to their importance to the project. Of those a subset is implemented on the hosting software (nQuire toolkit) and tested. Thereafter, the next stages for the community creation are described: the recruitment of members in the community and the use of engagement techniques and strategies for sustaining participation.

Chapter Six demonstrates how the results of Weather-it project were collected and analysed. Each of the design aspects (online community, engagement, inquiry, and software) are considered by exploring quantitative and qualitative data across log files, interviews and questionnaires. Main findings include the importance of: moderator and frequent communication with the members through social media and emails, notification system for updates and responses, multiple ways of participation, software usability, ways of interaction between the members, inquiry activities as part of a complete scientific process, and balance between fun and scientific literacy gains. Furthermore, disengagement factors (lack of time, interest and confidence) and levels of learning (activity, on-topic and community) are identified.

Chapter Seven integrates the findings of Inquiring Rock Hunters and Weather-it projects. The findings are considered in the context of the research questions and explained in comparison to other previous research on citizen participation and other online communities. Possible explanations for the findings are also discussed. The chapter concludes with some design considerations for the creation and enhanced engagement of future Citizen Inquiry and other citizen participation communities.

Chapter Eight concludes the thesis by identifying the contribution of the research in relation to the research questions. Some potential limitations of this study are also considered. The chapter concludes with an agenda for future research, proposing research questions emerging from this thesis, for the further exploration of the field.

Chapter 2: Literature Survey

2.1 Introduction

This literature survey focuses on aspects of citizen participation in scientific research and online communities that will help in facilitating the creation of a citizen participation community for inquiries. Hence, it considers work exploring models and typologies of citizen participation projects, informal learning, evaluation frameworks and the role of citizen in public participation with science projects. It also reviews IBL and presents how Citizen Inquiry has emerged. Finally, it reviews current literature focusing on the creation and sustainability of online communities and examines why and how people participate in online communities of different types.

2.2 Public Participation in Scientific Research

Evidence shows lack of scientific literacy, according to the Public Attitudes to Science reports (Ipsos MORI, 2011, 2014). The Public Attitudes to Science surveys reveal that although citizens recognise the benefits from involvement in science and technology, they experience difficulties in gaining information and developing understanding.

The Public Engagement with Science (PES) ‘dialogue’ or ‘participation’ model (McCallie et al., 2009) was developed to engage the public in shared scientific activities and science understanding. An important component of PES is close collaboration between science experts and non-experts. Members of the public are encouraged to engage in science-related activities of their own choice (Scanlon, 2012) and gain access to scientific knowledge.

The Centre of Advancement of Informal Science Education (CAISE), affords high status to citizen science, establishing a citizen science inquiry group called Public Participation in Scientific Research (PPSR) focused on exploiting citizen science to boost public participation in science (McCallie et al., 2009). Citizen science projects are defined as *“Projects in which volunteers partner with scientists to answer real-world questions”* (Citizen Science Central, 2015). PPSR

engages lay people with aspects of the scientific enterprise whilst the collaboration between scientists and public volunteers in citizen science projects is an increasingly popular way for the advancement of informal science education (McCallie et al., 2009).

2.2.1 PPSR projects

Early citizen science projects like Christmas BirdCount¹ (Root, 1988) pre-date the Internet and the observations were often reported through the mail (Raddick et al., 2010). Nowadays, these observations are reported through the Internet allowing the mass participation of citizens in research in many different ways. The digital era has boosted the role of the amateur in science involving them in authentic scientific research (Alexander, 2008; Bohannon, 2009; Grey, 2009; Hand, 2010). In turn citizens have increased their impact on scientific endeavour (Mason, Michalakidis & Krause, 2012).

2.2.2 Typologies of PPSR projects

An educational-focused research project by Bonney et al. (2009), having in mind the “Science for/by/with the people” phrase, examined the stages of inquiry in which people participate. They categorise PPSR projects into three clusters according exclusively to the level of collaboration between the scientists and lay people: contributory, collaborative and co-created projects. The *contributory* projects (e.g. The Birdhouse Network²) are generally created by scientists, and members of the public contribute and sometimes analyse data. The *collaborative* projects (e.g. Invasive Plant Atlas of New England³) are also designed by scientists but the public can also help with the methodology design and results dissemination. The *co-created* projects are a more demanding model sometimes called *participatory* action research (Cornwall & Jewkes, 1995; Ballard & Huntsinger, 2006) and only a few projects are included in this category (Bonney et al.,

¹<http://birds.audubon.org/christmas-bird-count>

²<http://www.birds.cornell.edu/Publications/Birdscope/Winter2001/birdhouse.html>

³<http://www.eddmaps.org/ipane/>

2009). In these projects, scientists and public work together in most or all the research phases. Some examples are Sherman's Creek Conservation Association⁴ and Citizen Sky⁵.

An extended typology (Shirk et al., 2012) includes two more clusters, called models, each lying at the far boundaries of the existing categories: the contractual and the collegial. The *contractual* model allows the public to raise questions of concern, usually community-relevant, for the scientists to research and produce knowledge. Members of the public are part of the research agenda but do not participate in the research process. The *collegial* model, at the other end of the spectrum, concerns amateur scientists, whose work is submitted for peer review and publication, leading sometimes to collaboration with professional scientists. This independent participation in the research process by non-traditionally credentialed scientists may require reconsideration of expertise (Ellis & Waterton, 2004; Evans & Collins, 2007).

Preliminary work by Haklay (2011) classifies online citizen science in three categories based on the participation activity: volunteered (distributed) computing, volunteered (distributed) thinking and participatory sensing. The citizen science projects of the first category involve more 'passive' participation as they harness the CPU power of the public when their computers are idle but still connected to the Internet. Distributed thinking projects have been available since 2005 and their aim is to utilize citizens' thinking and their active engagement in scientific research. One of the first distributed computing projects, SETI@home⁶ (Anderson, 2004), was launched in mid-1999 and has been employing volunteers' CPU power to search for signatures in the Arecibo Radio Telescope data that may carry the indication for the existence of extra-terrestrial life. Distributed thinking projects started during the Rosetta@home⁷ distributed computing project (creation of protein structures), when eventually the coordinator of the project was receiving more efficient suggestions from the people who were watching their computers while working and as a result an

⁴ <https://www.facebook.com/ShermansCreekConservationAssociation/>

⁵ <http://www.citizensky.org/>

⁶ SETI@home

⁷ <http://boinc.bakerlab.org/>

on-line game called Foldit⁸ was created, where the participants can contribute actively by folding proteins in puzzles in order to help deduce the 3-D structure of protein molecules (Bonetta, 2009). In the third category of participatory sensing, mobile phones are used to sense the environment through integrated sensors (e.g. GPS, camera, accelerometer, etc.), record the observations and report them for research purposes. For instance, the smartphone application 'WideNoisePlus' (Becker et al., 2013) was developed within the EveryAware project (EveryAware Project, 2012), which aims to help citizens to collect, share and understand their environment through measuring air pollution and noise. Holliman and Curtis (2014) propose 'citizen science games' as third category instead, developing a revised typology. In citizen science games participants help to solve a scientific research problem through a stylised games interface (Cooper et al., 2010; Kawrykow et al., 2012). Curtis (2015) revised this typology by developing a classification based on the tasks rather than the projects. 'Distributed computing' projects exploit computing processing power, requiring passive participation from the citizens; 'distributed data analysis' projects provide more active engagement with classification, annotation and other activities; and 'distributed collaboration' projects require active collaboration of participants for the completion of project tasks.

Wiggins and Crowston (2011) in their citizen science typology analysis identified a wide range of facets, such as organizational features, participation design, educational features and outcomes, describing the citizen science projects. Afterwards, they used these facets to sort the projects accordingly and they classified the projects in five categories: Action, Conservation, Investigation, Virtual and Education. Action projects follow a bottom-up approach with the volunteers getting involved in local concerns while collaborating with researchers. These projects are mainly supported by simple websites and their main goal is finding evidence for intervention. An example is Sherman's Creek Conservation Association, which was formed to engage citizens in stream cleanup events, watershed monitoring and other community outreach programs (e.g. Wilderman, 2004). Conservation projects include top-down or middle-out approaches where citizens are

⁸ <http://fold.it/portal/>

engaged in data collection activities. The aim in these projects is gathering data for resource management decision-making (e.g. The Northeast Phenology Monitoring⁹). Investigation projects are of top-down structure where the volunteers' role is observation and report. These kinds of project support ongoing learning, can be local or international, employ a wide variety of technologies and focus on scientific research goals requiring data collection (e.g. The Great Sunflower Project¹⁰). Virtual projects follow the top-down approach where all project activities are ICT-mediated and the citizens provide an important service in data reduction by classifying/recognizing images. For these projects advanced technology is being used with game-like tasks (e.g. Galaxy Zoo). Education projects are top-down organized with designed tasks that provide learning experiences as Education is the main purpose of the projects. They usually are short-term projects which focus on a science field and include a research partner (e.g. Fossil Finders¹¹).

Haklay (2013) in later work developed a typology that focuses on the level of participation and engagement, consisting of four levels. 'Crowdsourcing' is the basic level in which the participation is limited and citizens provide resources either by using experiment sensors or donating their computer power for the analysis of large volumes of data. 'Distributed intelligence' in the second level uses the cognitive ability of the project participants who are asked to carry out simple interpretation activities after taking some basic training. In 'participatory science' or 'community science' which is the third level, citizens may define the problem and then with the assistance of scientists set the data collection method, analyse and interpret the results. Citizens, however, do not participate in the detailed analysis of the results as they may lack the scientific knowledge required for inferring scientific conclusions. In the last level 'extreme citizen science' problem definition, data collection and analysis are integrated collaboratively, offering participants the opportunity to utilise the results and take part in publications. The whole process may be carried out by participants to achieve a specific goal and scientists act as facilitators.

⁹<http://www.nerpn.org/>

¹⁰<http://www.greatsunflower.org/>

¹¹<http://www.fossilfinders.org/>

Table 1 lists the different typologies in an effort to provide an overview of all the potential types of citizen science projects. In the table, several models and types of projects are compared and matched based on their similarities in terms of activities, type of participation and goals. The results are shown in ranking levels based on the level of participation and the goals of every PPRS type of project. Therefore, the first level (Level 1) consists of contractual projects where the members of the public determine the research agenda setting the topic of the investigation but do not participate in it.

Most of the project types fall into the second level of contributory category (Level 2), which can be divided in two groups as the activities require either passive/active/collaborative data collection or/and analysis. The members of the public may use several collection and analysis methods and serve a number of project goals. Therefore, the activities may involve crowdsourcing exploiting passive distributed computing and participatory sensing (Level 2a), or a more active involvement using distributed thinking/intelligence, games and virtual projects (Level 2b). These activities aim to help investigations and conservation projects seeking for resources to explore scientific research goals and proceed to decision-making.

In Level 3, collaborative projects are still initiated by scientists, but members of the public may refine the design and participate in research phases beyond data collection and analysis. By comparison, co-created projects in Level 4 involve members of the public in almost all the research phases. Furthermore, in participatory or action projects the research is initiated by members of the public who seek for scientists to act as collaborators or consultants after the problem is defined.

Table 1: Public participation in scientific research – typologies of projects

Levels	Bonney et al. (2009)	Wiggins & Crowston (2011)	Haklay (2011)	Shirk et al. (2012)	Haklay (2013)	Holliman & Curtis (2014)	Curtis (2015)
1				Contractual			
2a	Contributory		Distributed Computing	Contributory	Crowdsourcing	Distributed Computing	Distributed Computing
			Participatory Sensing				
		Investigation					
		Conservation					
2b		Virtual	Distributed Thinking		Distributed Intelligence	Distributed Thinking	Distributed Data Analysis
						Citizen Science Games	
3	Collaborative			Collaborative			
4	Co-created	Action		Co-created	Participatory Science		
5				Collegial	Extreme Citizen Science		
		Education					

In Level 4 members of the public get involved in independent or collaborative research, utilise results and take part in publications. In Level 5, extreme citizen science, participation is in collaboration with credentialed scientists whilst in collegial model amateur scientists publish independently and go through a peer-review process with expert scientists.

Many of the PPSR projects provide educational materials or training that support ongoing learning and improve members' participation in the research (Bell et al., 2009; Bonney et al., 2009; Crall et al., 2012; Freitag & Pfeffer, 2013). However, some projects have education and outreach as their primary goals instead; these are called *Education* projects and are not enlisted in any of the levels in the Table 1 as their design and tasks are educational-oriented and do not aim to produce

scientifically valid results (Wiggins & Crowston, 2011). In some cases these education projects collaborate with a research partner and involve contributions to a research project. In this case, the Educational projects may also fit in the Level 2 of participation.

Table 2: Initiation and activity – comparison of PPSR projects

		Initiation	
		Scientists	Citizens
Activity	Scientists	N/A for PPSR	Contractual
	Citizens	Contributory	Participatory/Collegial
	Both	Collaborative	Extreme Citizen science

Table 2 summarises types of projects based on their initiation and activity. Thus, a project may be initiated by scientists or by citizens, and the activity may be run by scientists, or citizens, or both.

An example of a popular online citizen science project is Galaxy Zoo¹² (Figure 2) which has enabled hundreds of thousands of people interested in astronomy to map and classify millions of galaxies in the universe according to their shapes. The project is run by scientists and the results, analysed by them, give information about the galaxy morphology, black holes and star formation.

Galaxy Zoo is a contributory project allowing its participants to help in the phase of data analysis. It can be considered as a virtual citizen science and distributed thinking/intelligence project as it provides an interactive application for the galaxy classification and uses the cognitive ability of participants.

¹² <http://www.galaxyzoo.org/>

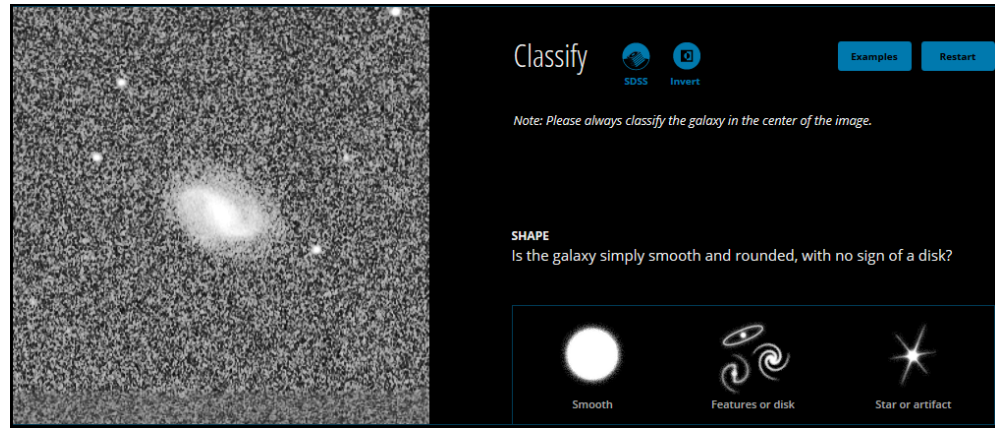


Figure 2: Galaxy Zoo

2.2.3 Informal Learning in PPSR

“Citizen science is often employed as a form of education and outreach to promote public understanding of science. The current form of citizen science, which has evolved over the past two decades, places more emphasis on scientifically sound practices and measurable goals for public education. Technology is credited as one of the main drivers of the recent explosion of citizen science activity.” (Ballard & Huntsinger, 2006)

Citizen science can be considered a powerful tool for public education as it contributes to the advancement of the scientific literacy, informs about specific sciences and the scientific method and it brings new voices to the scientific research (Duke & Tonkin, 2012). What distinguishes citizen science as an informal learning experience is the engagement of the public in authentic science and fostering of ways of critical thinking for decision making, similar to those of scientists (Jordan, Gray & Howe, 2011; Jordan, Crall & Gray, 2015). The term ‘engagement’, in informal science education, is not used to describe the involvement of audiences in learning about science, which shows a one-way transmission of knowledge from experts to publics, but the mutual learning among all of the participants (Bonney et al., 2009). The National Research Council (Bell et al., 2009) examines participation in science learning within informal settings and discusses how it provides space for all learners to engage with ideas and bring their prior knowledge and experience to bear. Moreover, it indicates that learners prosper in environments that

acknowledge their needs and experience, and highlights the critical role of mentors, peers and facilitators in supporting informal science learning.

Participants in PPSR projects enjoy a social community (Raddick et al., 2010) and are able to contact professional scientists, participate in real science and experience the process of science. In addition, PPSR projects increase public awareness of environmental and scientific challenges and may improve decision making skills (Galloway et al., 2006; Alabri & Hunter, 2010). They develop interest in something new or expand previously existing interests and connect their interests to science, proving that science can be fun (Bonney et al., 2009). Moreover, inquiry experiences can provide valuable opportunities for members of the public to improve their understanding of both science content and scientific practices (Edelson, Gordin & Pea, 1999) and citizen science makes them available.

According to evidence-based research by Kloetzer et al. (2013), three levels of learning can be identified in PPSR projects. The first level is related to the mechanics of the activities (activity learning) the second focuses on the project and the science behind it (on-topic learning) and the third is associated with the learning within the community (community learning). Still, the organisation of citizen science projects shows that scientific goals in citizen science projects precede the learning goals. As a result, citizen science volunteering projects train participants towards the completion of the project targets, rather than focusing on the enhancement of their knowledge, skills and understanding of the topic. For instance, Bonney et al. (2015) in their review of data collection and data processing PPSR projects (Level 2 in Table 1), although they identify that scientific outcomes are well documented in PPSR projects, evaluate the gains of the participants in science knowledge and processes as limited.

2.2.4 Evaluation frameworks in PPSR projects

In the last few years several evaluation frameworks have been used or developed in order to assess the scientific and learning outcomes of PPSR projects.

Bonney et al. (2009) used the framework provided by Friedman (2008) in a meta-analysis of PPSR projects, including contributory, collaborative and co-created projects to evaluate the learning outcomes of PPSR. The framework contains a set of categories for measuring the outcomes of learning technologies used in informal science learning. The categories include awareness, knowledge or understanding, engagement or interest, attitude, skills and behaviour. The instruments for measuring the outcomes used for the analysis of the projects included pre/post-tests, self-report questionnaires, interviews, observations, surveys, documentation of participation and co-authored publications. The results showed that the participants in all PPSR projects increased awareness, knowledge and understanding of key scientific concepts. Regarding the science process, understanding of participants in co-created and contributory projects who were engaged in the project design and data interpretation, or most importantly the full research process, showed increased understanding of the scientific process. On the other hand, participants in contributory projects were reported to have increased their inquiry skills but to a lesser extent. This might show evidence that the more the involvement, the more science understanding by the participants increased.

In the same meta-analysis report, it is noted that although some projects document improved attitudes toward science, they do not use formal instruments to measure the change. Results from other studies that assess the scientific literacy of citizen volunteers with the use of instruments, demonstrate a lack of statistically significant difference between the pre/post-tests (e.g. Brossard, Lewenstein & Bonney, 2005; Cronje et al., 2010; Jordan et al., 2011; Crall et al., 2012). Explanations about the outcomes include the motivation of participants to study and learn about the topic rather than to learn about the scientific process. Moreover, mentioning the scientific methodology during the training event in Cronje et al. (2010) did not succeed in improving the results.

Jordan, Ballard and Phillips (2012) identify the need for balance between learning goals and scientific goals in a citizen science project. In other words, there must be a balance between the data collection to be achieved and the expected broad learning goals. The evaluation plan should

ensure that the learning goals are consistent to the project activities, the learning outcomes are presented with clarity, and both of them can be measured through some indicators (Phillips, Bonney & Shirk, 2012). An evaluation framework has been proposed by Jordan et al. (2012) suggesting a 3-scales evaluation framework for measuring citizen science project outcomes. The project activities should reflect the learning or scientific priorities, explicitly stating the project goals. The evaluation measurements are developed around learning (e.g. science process and inquiry skills), programmatic (e.g. understanding of community issues) and community-level outcomes (e.g. social capital).

Similarly, Bonney et al. (2009) in order to ensure that the objectives of a citizen science project have been met, introduce a more detailed framework with measures which could be used to evaluate separately the scientific and educational outcomes. The scientific measures comprise of counting the number of publications, citations, graduate thesis and grants achieved by the project, the size and quality of the data collection, and the frequency of media exposure of results. The educational outcomes are suggested to be measured through the duration of participants' engagement with the project and the number of their visits to the project and also via their improved understanding in science content and process. The improved scientific skills and attitude toward science as well as the increased interest in a career in science are considered among the possible measures. To this end, Bonney et al. (2009) recommend some measurement techniques, such as in-depth interviews, self-reported knowledge and focus groups.

The importance of scientific outcomes has also been stressed by Kim et al. (2011) who discuss the problem of data quality, wondering whether the submitted data is useful. In addition to that, they bring up the issue of the success of a citizen science project: the evaluation measures should not only include the levels of engagement and the amount of collected data, but also the usefulness of the contribution.

2.2.5 Citizens in PPSR projects

PPSR projects engage members of the public in working with scientists. Yet, there has been little research into conceptualisation of citizenship within these projects.

Despite the focus of recent citizen science on ‘citizens as scientists’ (Lakshminarayanan, 2007; Conrad & Hilchey, 2011), the role of citizens in many projects has been described as “observer and recorder” rather than as “leader and originator”; this mode of involvement has been characterised as a cheap way to monitor and gather data (Alabri & Hunter, 2010; Conrad & Hilchey, 2011) and being an instrument of the scientist (Stodden, 2010).

As opposed to this, some studies have indicated that the citizen agenda is supported by the use of online discussion forums for citizen-led investigations where the public proposes questions while participating in a citizen science project (Fortson et al., 2011; Luczak-Roesch, Tinati & Simperl, 2014). Such interactions may also benefit the project in terms of attracting interest and enhancing long-term engagement (Mugar et al., 2014) or contribute positively to social wellbeing by giving people a voice in decision making (Bonney et al., 2015).

Nonetheless, a recent review on the role of citizen in citizen science projects identifies that from an educational standpoint, not much research has been yet undertaken (Edwards, 2014). Hence, it is still vague how citizens gain knowledge of the scientific area and learn through their participation.

2.2.6 Conclusion

There have been efforts to use citizen science projects as tools for the citizens to gain informal science learning experiences and scientific literacy. It seems, however, that science learning in PPSR projects happens mainly as a side effect due to formalising training which aims to the successful completion of the scientific goals, rather than educational design that intends to improve the learning outcomes. Only a few projects conduct research to improve learning outcomes while most of them focus on the evaluation of scientific outcomes and how to increase

the contributions. Moreover, although it is suggested that citizen science projects involve participants in authentic science, they usually do not engage them in all the research phases. As a result, citizens are placed at the periphery of the authentic context, where they are usually limited to collecting or processing data. Nevertheless, there is evidence that citizen science projects succeed in bringing scientists closer to citizens, increase the public awareness of scientific issues and make science look more fun.

2.3 Inquiry-based Learning

Beyond PPSR projects, IBL has been suggested as another way to engage citizens with science. The term inquiry was first used by Dewey (1910) to invoke the idea of teaching science in the same way that scientists implement their research. Thus, learning science should include formulating and testing hypothesis by using problem solving skills (Dewey, 1910; Schwab, 1960). Dewey (1938) also referred to inquiry as a *“felt difficulty”* situation when something is unexpected in response to everyday life and needs investigation.

A more recent study by Sundberg and Moncada (1994) describes laboratories for science teaching as “cookbooks” where students are told what to do and what to learn. Chinn and Malhotra (2002) refer to the high school inquiry tasks mentioned that are comprised of simple inquiry tasks such as simple observations, illustrations and easy experiments and they do not coincide with authentic scientific reasoning.

To address the abovementioned deficiencies, the US National Research Council (1996) proposed changes to science teaching that engage learners in authentic inquiry and research. It is suggested that science inquiry places learners in an environment that contributes to *“asking questions, planning and conducting an investigation, using appropriate tools and techniques, thinking critically and logically about the relationships between evidence and explanations, constructing and analysing alternative explanations, and communicating scientific arguments”* (National Research Council, 1996, pp. 105).

2.3.1 IBL and personal meaning in science

“At the nexus of science education and participatory democracy is a commitment to educating students to make more informed choices, think critically, and believe they can make a difference”.
(Mueller & Tippins, 2012).

Inquiry was set to play an important role in science education (American Association for the Advancement of Science, 1994) and the effort of educating students to use scientific knowledge to solve problems led to more student-centred and active learning approaches such as IBL. IBL involves a departure from content-led learning and at the same time enhances 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 (Oberhauser & LeBuhn, 2012). The underlying question behind IBL is whether such learning methods can achieve the goal of science education and produce scientifically literate citizens.

In response to that concern, the importance of authentic scientific practice in science education has been recognised (Michaels, Shouse & Schweingruber, 2008). A further point is the need for personal meaning in science. Mueller and Tippins (2012) state that despite all the efforts carried out to reform science education, it still operates on the assumption that knowledge in every discipline is detached from the others and is presented as a body of isolated facts that have nothing to do with the real world.

Based on results from the Public Attitudes to Science report (Ipsos MORI, 2011) one third of the people who disengaged themselves from science say that school put them off science. These results may be linked to the idea that science lessons at school are in general disconnected from daily life (Diamond, 2006). The personal commitment that rises from the learners' personal interest in something is an element that is missing from classrooms (Chinn & Malhotra, 2002). Personalising inquiry provides students with the opportunity to reflect on how science may impact upon their own lives and how their behaviours may be contributing to the phenomenon they are studying (Scanlon, Anastopoulou & Kerawalla, 2012).

2.3.2 IBL orchestration

The National Research Council (1996) pointed out that new avenues for scientific inquiry need to be explored. Informal science education programs (Crall et al., 2012) as well as authentic inquiry practices and science outside the classroom could provide such venues.

The Personal Inquiry project¹³ shows how the orchestration of classroom learning can be extended to IBL in informal settings (Sharples et al., 2014). The project was a collaboration between The Open University and the University of Nottingham and engaged young people aged 11-14 in an authentic scientific process that aimed to help them understand themselves and their world.

Dynamic representation of the IBL process allows learners to shape the process of investigation and understand the fit of the component activities (Littleton & Kerawalla, 2012). Thus, a challenge for PI was to produce a structure that will guide the inquiry process, support discussion and enable sharing of results (Sharples & Anastopoulou, 2012). Drawing upon representations designed for structuring inquiry in the classroom (e.g. Shimoda, White & Frederiksen, 2002), a generic depiction of the personally meaningful IBL process was produced (Scanlon et al., 2011). The scientific inquiry is shown as a cycle in the shape of octagon and involves the steps 'find my topic', 'decide my inquiry question', 'plan my methods', 'collect my evidence', 'analyse and represent my evidence', 'respond to my question', 'share and discuss my inquiry' and 'reflect on my progress'. This 'scripted inquiry' was assisted by the inquiry toolkit, nQuire, which runs on personal 'netbook' computers and desktop computers. Figure 3 shows a snapshot of the inquiry diagram in the nQuire platform from the PI project 'Healthy Eating'.

¹³<http://www.pi-project.ac.uk/>

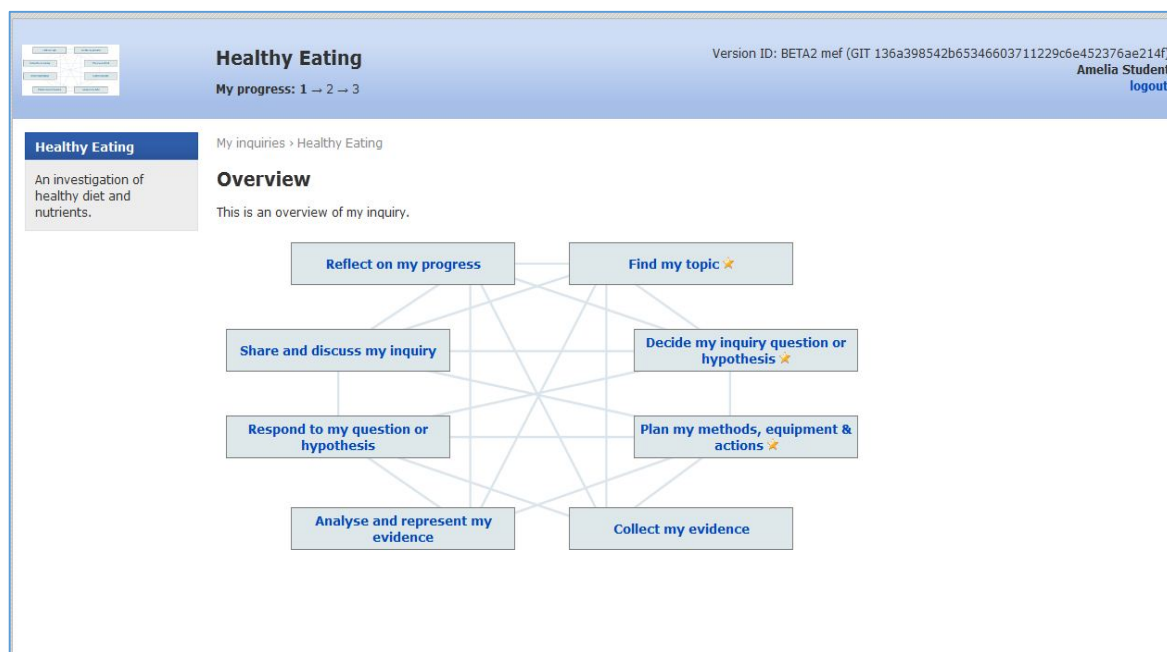


Figure 3: Personal Inquiry – healthy eating

Learners typically start a science investigation in the classroom managed by a teacher, then continue it at home or outside, supported by *nQuire*, then share, discuss, and present their findings back in the classroom. Findings of a controlled study of children’s scientific inquiry skills for the Personal Inquiry project showed that the group who engaged with the *nQuire* investigation made *“a significant improvement in the accuracy of their decisions from pre- to post-test, while a non-intervention control group did not”* (Sharples et al., 2014).

Other IBL projects are the Learning Ecology with Technologies from Science for Global Outcomes are (LET’S GO)¹⁴ science learning project between Stanford and Linnaeus Universities in partnership with Intel, Pasco, the National Geographic Society, the Science Created by You (SCY)¹⁵ European FP7 funded project and the Web-based Inquiry Science Environment (WISE)¹⁶ project. In these projects, learners were given scientific activities to carry out with the use of supportive, interactive technology inside and outside the classroom. Activities were guided by teachers, domain experts and technology toolkits, showing the value of orchestrating IBL (Littleton, Scanlon & Sharples, 2012).

¹⁴ <http://celekt.info/projects/show/20>

¹⁵ <http://www.inspiring-science-education.net/home>

¹⁶ <https://wise.berkeley.edu/>

2.3.3 Conclusion

The above projects are good examples of IBL orchestration but have been conceived as extensions of school science as they require a 'teacher' to have the central role. Yet, people of all ages need support in order to act as scientists, by carrying out appropriate investigations, collecting and examining authentic data, and presenting their results in a systematic manner (de Jong, 2014).

The next section describes an approach that fosters science learning experiences within distributed communities of learning by combining aspects of Citizen Inquiry with IBL.

2.4 Citizen Inquiry

The main idea of Citizen Inquiry is to open up the scientific process to distributed communities of citizens to conduct and report inquiry-led projects. However, the question is how can non-scientists engage in this challenge of inquiry? As described in Section 2.2, in most of the PPSR projects the research questions and methods are set by scientists, and citizens contribute to one or more inquiry phases such as the data collection and analysis. In this way, most of the time citizens do not participate in deciding the research agenda and process. Repositories for citizen science projects such as Scistarter¹⁷ provide the opportunity to create and add projects to the platform but without any inquiry supporting mechanism.

Citizen Inquiry merges the knowledge of IBL with the civic engagement of citizen science projects and produces a method for involving citizens with science whilst enabling their engagement in the entire investigation process (Sharples et al., 2013; Aristeidou, Scanlon & Sharples, 2013). Therefore, citizens propose investigation topics, set research questions and methods, conduct investigations, and share and present findings. The challenge for Citizen Inquiry is the design of a structure, able to support the process of personally meaningful IBL in small or large scale projects.

¹⁷ <http://www.scistarter.com/>

2.4.1 Citizen Inquiry Orchestration

Important components of the orchestration of Citizen Inquiry are collaboration, knowledge sharing and peer review (citizen science) as well as experimentation, discovery, critique and reflection (IBL). Moreover, Citizen Inquiry offers an informal learning mechanism as it is developed outside the curricula of formal education and is being driven by the personal interest of citizens employing their everyday experience with science and its underpinning reasoning (Aristeidou et al., 2013).

Similar to IBL, it engages citizens with scientific activities such as collecting data, conducting experiments and reflecting on their work (Dewey, 1933; White & Frederiksen, 1998). 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. There is also evidence that authentic scientific activities and material ownership that reflect the everyday life activities may even engage learners with unexciting data (Woodgate et al., 2008). It is also important that they engage in authentic scientific inquiry themselves instead of participating on the “*periphery of authentic contexts*” (Schwartz, Lederman & Crawford, 2004) through simple practices, as in other types of PPSR projects.

Furthermore, Citizen Inquiry provides social community similar to citizen science projects with the opportunity to interact with science experts. Regarding the level of citizen participation in PPSR, it falls closer to Level 5 (Table 1) and in particular in *extreme citizen science* as the participants conduct research and disseminate results in collaboration with other citizens and credentialed scientists. To this end, the participants of Citizen Inquiry projects are expected to be active during the entire project, but also to improve their understanding of science and develop skills used by scientists. It is also anticipated that the perspective of self that personal inquiries support, may enhance the reflection of citizens about scientific inquiry and the nature of science (Schwartz et al., 2004).

Table 3 shows the main components of the orchestration of Citizen Inquiry. Fusion between aspects of citizen science and IBL produce Citizen Inquiry which in turn, as discussed, requires personal meaning, everyday experience and autonomy from participants. The project is then led by the scientific field which informs the knowledge methods and tools. Finally an online environment hosts the orchestration, consisting of the online toolkit and community.

Table 3: Citizen Inquiry components

Scientific field	Citizen Inquiry		Online environment
	Citizen science	IBL	
<ul style="list-style-type: none">• Field knowledge• Field methods and tools• Interest in field	<ul style="list-style-type: none">• Collaboration and knowledge sharing between expert scientists and non-experts• Mentoring from experts• Peer review• Informal settings	<ul style="list-style-type: none">• Authentic inquiry science: Experimentation, discovery• Scientific skills: Development: planning, employing scientific tools, critique, reflection• Active investigation: during the entire inquiry, form their own questions	<ul style="list-style-type: none">• Inquiry and Communication tools• Community and interactions
	<ul style="list-style-type: none">• Personal meaning• Everyday experience• Autonomy		

Creating an online environment for Citizen Inquiry requires difficult design decisions, as the interactions (knowledge and methods exchange) are supported and guided by online systems and tools within a web-based inquiry environment. This inquiry-led system also addresses suggestions from previous studies on PPSR for placing more focus on putting the material to be presented in the context of the scientific method (Cronje et al., 2010; Crall et al., 2012).

2.4.2 Online community of Citizen Inquiry

An online community is any virtual social space that has a purpose, is supported by technology and is guided by policies (e.g. registration policies, language) (Preece, 2001). Preece (2001) also discusses that online communities differ from other software because of interactions among people. People in online (or virtual) communities come together in order to give or receive information and support, learn, and find company. The type of the community can vary according to its purpose. Some communities are created to support practices and professional discussions. These communities are referred to as Communities of Practice: *“Communities of practice are groups of people who share a concern or a passion for something they do and learn how to do it better as they interact regularly”* (Wenger, 1998). A different type of online community, ‘Community of Interest’, supports interest groups, and the discussion is formed around the topic of interest of the members – pets, football, books, etc. (Preece, Nonnecke & Andrews, 2004).

The communities formed within this study, are online communities of Citizen Inquiry in which citizens will engage in the process of knowledge sharing and collaborative learning while being involved in scientific investigations. Thus, the scientific field and topics provide the domain that participants are interested in. The participants of any level of expertise engage in joint investigations and build relationships through the inquiry and the discussion while interacting and sharing resources.

In online communities of practice, the possibilities for a member to generate value and share knowledge with other people are increased (Cheung, Lee & Lee, 2013). Helping others provides members with feelings of pleasure (Lakhani & Wolf, 2003; Wasko & Faraj, 2005). Reciprocity – the expectation for future returns – is also shown to be an engaging factor (Chiu, Hsu & Wang, 2006; Oh, 2012). According to Wenger (2010) an online community can be viewed as a social learning system and learning is both the activity and the product that occurs. Therefore, a learning activity may be a conversation between the members consisting not only of words but also images, video and other multimedia; dynamic and interconnected resources which are generated by all the

members of the community (Downes, 2010). Lave and Wenger (1991) characterise learning within a community as a process of increasing participation, called 'legitimate peripheral participation'.

A learning community may engage its members in critical discourse and reflection, so they collaboratively construct meaning and mutual understanding (Garrison, 2007). Regarding the learning taking place in online/distant communities, Paloff and Pratt (2010) state that the learners are given the chance to extend and deepen their experience, to test and share the ideas with the group and receive constructive feedback. In this way, there is "the formation of a learning community through which knowledge is imparted and meaning is co-created" (Palloff & Pratt, 2007, p. 4). The emphasis on mutual understanding and meaning co-creation echoes the needs of a community for Citizen Inquiry which aims to engage the members in such activities as to promote their critical thinking and reflection on the received information in a collaborative way.

A distinct type of a learning community similar to Citizen Inquiry is 'Community of Inquiry'. It was developed through a framework in which *"group[s] of individuals collaboratively engage in purposeful critical discourse and reflection to construct personal meaning and confirm mutual understanding"* (Garrison, 2011, p. 15). This framework consists of three elements – 'cognitive', 'social' and 'teaching' presence – and is based on experimental inquiry, following a cyclical process which starts with a question being explored to reach a solution. In this community teachers and learners are engaged with intellectual issues, thinking critically about them, aspects that are proposed to be essential for obtaining high order learning (Garrison & Arbaugh, 2007). Communities of Inquiry serve mainly formal education where the teaching presence is available.

The iSpot¹⁸ natural history project (Figure 4) falls close to a Citizen Inquiry approach. It was developed by The Open University and it is a community for citizen engagement with wildlife observation. The aim of the project is to help people learn to identify wildlife by bringing experts and amateurs together using a platform which encourages learner collaboration (Woods & Scanlon, 2012). For the user-generated content, it provides a crowdsourced identification system

¹⁸ www.ispotnature.org

for the users to identify observations made by other contributors, in this way providing evidence of the users' understanding of nature. Beyond the identifications, a new feature on the iSpot platform allows citizens to explore plants and animals in nature by starting their own projects, for instance a collection of observations based on a selected location. Although citizens may decide the topic, the research methods supported by the platform are limited to observation and identification. However, the iSpot community carries many aspects at the intersection of citizen science and IBL, such as collaboration, knowledge sharing, active investigation, community interaction, methods and tools.

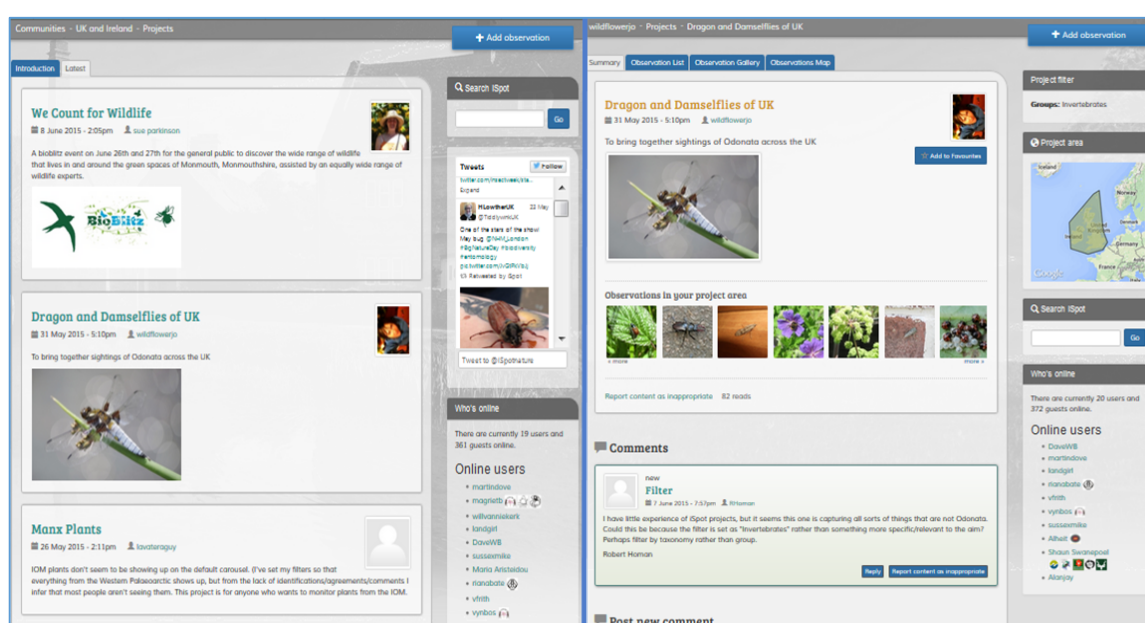


Figure 4: iSpot

Citizen Inquiry can be a powerful tool to engage people with science through collaboration in scientific practices. Engagement in a community according to Polin (2010) leads to a dual process of meaning making. The members of the community participate in the social life of the community while at the same time they produce artefacts, such as words, methods, resources which give reification to the community and mirror their shared experience in learning and knowledge exchange. This collaborative achievement, along with the spirit for its continuity, are the keys to the successful creation of an online learning environment and the promise of a

sustainable community (Cheung et al., 2013), significant aspects that are further explored in the following sections (Sections 2.5 and 2.6).

2.4.3 Conclusion

Citizen Inquiry aims to engage citizens in online communities supported by inquiry tools where they could conduct personally meaningful collaborative scientific investigations. Yet, how exactly citizens can adopt an inquiry process that follows good practices of science learning remains unclear. Furthermore, it is still uncertain whether this investigation of ownership in Citizen Inquiry can engage citizens and form sustainable communities. The findings of the first design study on understanding and engagement of citizens in online Citizen Inquiry (Chapter 4) suggested that there is a need to improve the sense of community within the members and maintain the engagement levels. Consequently, further research is needed on the creation, evolution and sustainability of online communities, including social networks.

2.5 Lifecycle of an Online Community

Examining the lifecycle of a community, by observing the activities and the growth, helps in monitoring the community and adjusting the approaches used within it in order to keep it active. In each stage the members have different needs and it is necessary to employ different tools, technologies or management activities; it is believed that this approach leads to success more efficiently (Iriberry & Leroy, 2009). The lifecycle consists of the following stages: potential, coalescing, maturing, stewardship and transformation (Wenger, McDermott & Snyder, 2002). It is not linear, as the process can be iterative and adaptable to the needs of the members and the purpose of the community (Young, 2013). The stages of the lifecycle are also encountered with different names, such as inception, creation, growth, maturity, death (Iriberry & Leroy, 2009) or with fewer stages, such as pre-birth, early life, maturity, death (Preece, 2000). In this survey, the categorisation of lifecycle stages by Wenger et al. (2002) is preferred as it provides a transformation stage instead of death.

2.5.1 Potential

At this first stage, the community is not quite a community yet, rather an idea. The idea of creating a community can either emerge because of a loose network of people who interact occasionally around a topic or because of an organisation or a person who wants, for example, to manage a needed capability. These two types of community of practice are called spontaneous and intentional, respectively, based on the way they are formed (Wenger et al., 2002). In intentional communities such as the Citizen Inquiry one, the key is to find an attractive topic that people are enthusiastic about and willing to share their opinion and their views (McWilliam, 2012). Once the vision of the new community is clear, the required technological components are selected and integrated, based on the needs of the initial and potential members of the community (Iriberry & Leroy, 2009). The first people who are interested in organising it are usually the people who take the lead to form the core-group of the community and spread the word (Malhotra, Gosain & Hars, 1997; Iriberry & Leroy, 2009).

Research has shown that the most important reason that people do not join a community is because they have never heard of it (Jamali et al., 2014). Therefore, the next step is to invite people to become members of the community. Resnick and Konstan (2012) demonstrate some useful steps one can take to bring a number of participants into the community. The two main proposed methods are impersonal and interpersonal (word-of-mouth) recruitment. A third independent way of attracting new members is the use of automated bots which simulate other members; as a result the community appears to be more active and thus more attractive to new members.

Even though word-of-mouth recruiting (passing information from person to person) is more powerful than impersonal advertising (Sultan, Farley & Lehmann, 1990), impersonal also works (Assmus, Farley & Lehmann, 1984) and is good for increasing the number of people who have little prior knowledge of the community. People tend to accept things that are familiar (Zajonc, 1968), therefore either using a name for the community which is linked to something popular and

successful (e.g. Wikipedia, Facebook), or placing tagging links on many sites (Resnick & Konstan, 2012) will increase their willingness to join the community. Resnick and Konstan (2012) also propose the exploitation of the 'early adopter' benefit to attract early members. This title includes the privileges of an early-bird joining the community such as, skills, status, reputation and privileges after the community becomes sustainable and therefore the newcomers will treat them with extra respect. Furthermore, endorsements from celebrities, related to the domain or not, can help to promote the community.

The explosion of internet use and social networks has made word-of-mouth a timely matter in research (Cox & Repede, 2013). Word-of-mouth recruitment can take place directly or indirectly. The moderator and the first members may recruit new members from their social networks sending out invitations to potential members. To this end, a useful design decision may be the integration of the community with other sites, making the user registration easy and fast by using their existing user identifiers so as to help get the word out (Resnick & Konstan, 2012). Moreover, the artefacts of the community speak by themselves and thus by adding an easy content-sharing feature which the members will be able to use simply and fast for exporting their content, the visibility of the community among the social network of the members will increase. Social networking campaigns have also been done by citizen science projects (e.g. Creek Watch) and were found to be as successful as an international press release, though less successful than recruiting from existing communities (Robson, 2012).

2.5.2 Coalescing

The creator[s] and the initial members begin to interact. With the entry of the new members in the community, it is really important to communicate the benefits of the community for those who do not want to spend time in exploring it; the new members may evaluate the community according to the descriptions and the reviews of the existent members (Resnick & Konstan, 2012). Moreover, the newcomers are more likely to remain in the community when the other members reply to their initial posts (Burke, Marlow & Lento, 2009). It is also advised that a community with

a clear identity will more easily attract new members (Andrews, 2002; Leimeister, Ebner & Krcmar, 2005).

The value of the community follows from the endeavour to discover the potential of the community and its contribution to joint problem solving (Iriberry & Leroy, 2009), which in this study are the topics of investigation. This stage is really important as the initial energy and interest can fall off with the members becoming impatient at not finding an immediate value and the creator[s] being unable to spark their interest (Iriberry & Leroy, 2009; Wenger et al., 2002). During this stage, however, the community begins to take shape; a rhythm is found and relationships are being built in a public or private way (Wenger et al., 2002). The creation of strong relationships is crucial in sustaining the members and it takes time as the members have to get involved in mutual help and knowledge sharing activities. These activities usually start within the public space through discussion and then might move to private interactions in which people get to know each other better and connect more.

The members, gradually, start to use common language, for example scientific terms, and select their roles inside the community (Iriberry & Leroy, 2009). A crucial leadership role in a community of practice is the 'core group', which plays a vital role in the success of the community, and all new members are potential members of this group (Young, 2013). Usually though, the core group consists of members who are experts on the domain and highly knowledgeable (Wenger et al., 2002). Some of their activities are to invite people, welcome the newcomers, connect people in the community, encourage lurkers (people who do not post) to join the discussion, and suggest improvements to the community (Young, 2013). Salmon (2012) in her five-stage model for successful online learning separates the e-moderation activities from the technical support. Thus, core group members may be facilitating the learning process or the community process. Another category of members in the community, are the active members who do not belong to the 'core group' and the peripheral members who seldom participate in the social interactions and focus mostly on the activities (Wenger et al., 2002). Some of the members provide information and

some others use this information (Nonnecke & Preece, 2000; Preece, 2001; Maloney-Krichmar & Preece, 2005; Ridings, Gefen, & Arinze, 2006).

In addition to the identity of the community, Wenger (2001) argues for the importance of the individual identity in a social learning system. A member of a community can express identity consciously or unconsciously (Kaplan & Haenlein, 2010) and this includes either personal information, such as name, age, gender, profession, location, or feelings, likes and dislikes. This concept of expressing the individual personality in the community is called *social presence* and is “the ability of learners to project themselves socially and emotionally, thereby being perceived as ‘real people’ in mediated communication” (Garrison & Arbaugh, 2007, p. 159). Social presence leads to increased interaction and engagement (Beuchot & Bullen, 2005). For the promotion of self-disclosure it is advised to provide the members with user profile pages which they will be able to personalise with their personal information and their pictures, as to reflect their identity (Andrews, 2002; Resnick & Konstan, 2012). Research has shown that the use of individual profiles and the access of those by the others, leads the members to more frequent visits, increasing their commitment with the community (Ren & Kraut, 2012).

2.5.3 Maturing

At this stage, the value of the community is already established and the next step is the development of a more focused communal self-conscious identity (Wenger et al., 2002). Thus, the members have useful things to share, stronger relationships, common vocabulary, roles and a shared communal culture that makes the community survive. The shared practice in the mature community requires thorough discussions and commitment as the activities become more focused and all the members should be included. At this point, the creators of the community have to make sure that they provide any additional resources needed (Wenger et al., 2002) and offer up-to-date and quality content (Iriberri & Leroy, 2009). In addition, for the newcomers to find the most active forums easier and join the discussion, a useful solution is to sort the forums by most recent activity (Resnick & Konstan, 2012).

Kraut and Resnick (2011) in their research identify factors that support and reinforce the participation and contribution of the members to the community. These factors mainly concern notifying the members about new activities and the need to contribute, encouraging them to contribute, setting goals, providing feedback, creating groups, promoting existing contributions and publishing participation levels. First, the members will only be able to contribute if they are aware of the needs and the content of the community; a suggestion on that is to publicize a list of activities the members could join along with a description of the work to inform the members about its content, what is required to do, and stress the benefits of contributing. A more targeted way to ask members to contribute to the activities, is to invoke their uniqueness in the group (Ling, Beenen, & Ludford, 2005) or notify just those people who have a particular interest in the specific task. The adoption of goals should be a strong motivator for the members to join and contribute to the activity, especially if they are challenging and specific. Preferably, the goals should have a deadline, either in terms of time (e.g. within a week) or in terms of contributions (e.g. first ten responses). Undoubtedly, frequent feedback to the contributors in respect of the goals, enhances their self-efficacy and their engagement in the activity and its goals (Locke & Latham, 2002). To this end, performance feedback, which builds a game-like comparative atmosphere, may have a positive effect on the motivation of the members to contribute. The completion of the activity should be accompanied by a reward, such as a prize or status reward (Iriberry & Leroy, 2009). Examples of such reputation systems within citizen participation projects are the ranking and badges employed by iSpot (Clow & Makriyannis, 2011), and the ranking and contests in Foldit¹⁹, an online game-like community to explore and contribute towards scientific exploration of protein folding.

A technique which can be exploited in order to persuade the members of a community to increase their participation and contribution, or even to initially join the community, is *social proof*. People believe that an action or belief is valuable when they are led to believe that other people embrace it too (Cialdini & Goldstein, 2004). Accordingly, the community should

¹⁹ <https://fold.it/portal/>

demonstrate all the types of contribution they have had by now; add indicators of participation levels and display the prominent user-contributed content which conveys activity within the community (Resnick & Konstan, 2012). The quality of the contribution is also really important as people will be more willing to keep contributing when they feel that the other members make equally valuable endeavour. Beyond the quality, another factor that can keep the members motivated to the community is the interaction with other people (Kubey & Csikszentmihalyi, 2013). Therefore, combining the contribution with social contact with the other members of the community will lead them to contribute more. Although social contact is essential for the members to participate in the activities of the community, it is discussed that people are more willing to contribute in a smaller group (Kraut & Resnick, 2011). Finally, a suggestion for addressing this issue, which is in line with creating investigations within the Citizen Inquiry community, proposes the creation of groups within the community (Kim, 2000).

2.5.4 Stewardship

In this stage, the community has established its identity. Yet, it continues to change after the maturity stage according to the environment, including activities, relationships and groups, while welcoming and accommodating successive generations of members (Wenger et al., 2002). The community can now advance its practice to its full potential; think about what they have done and what they have to do, while seeking for sources and relationships outside the community to import. Once the practice is established, the community strives for having a voice with respect to their domain (Wenger et al., 2002). The success of the maturity stage has now transformed the community into a formal organisation and the creator[s] have to ensure its sustainability (Iriberry & Leroy, 2009).

Research, however, shows that usually a small minority of users offer the majority of the content and that principle is called participation inequality (Cifforilli, 2003; Nielsen, 2006; Brake, 2014). This principle can also be encountered as the law of the few (Gladwell, 2000) or heterogeneity of the population (Oliver, Marwell & Teixeira, 1985) and the percentages range from 80% inactive and 20% contributors to 95%-5%. This phenomenon has also been observed in PPSR projects

(Curtis, 2015). Activating the majority of the members and trying to get them to be active contributors instead of lurkers is significant in this stage, for achieving the critical mass of members and member-generated content in the community. The critical mass is considered as the threshold that has to be achieved for reaching the collective action (Oliver et al., 1985) and the self-sustained community for further growth (Westland, 2010). Reasons for lurking include personal preference, environmental influence, individual-group relationship and security consideration (Sun, Rau & Ma, 2014).

In response to lurking, the commitment to the community is one of the most important motivations that keeps the community going (Bateman, Gray & Butler, 2010). The three-component model of commitment (Meyer & Allen, 1991) was developed to reflect the different psychological stages that support and attach the members to communities. According to this model, the members have one or more reasons to stay in the community: *they want to, they ought to, they need to*. These, correspond to the psychological states of *affective, normative* and *continuance* commitment.

The *affective* commitment is divided into the *identity-based*, the member is a part of the community, and *bond-based* commitment, the member is close to the other members. In the first case where the members are attached to the community, they are stable in the face of membership turnover (Abrams, Ando & Hinkle, 1998) and compliant with community norms (Postmes & Spears, 2002; Sassenberg, 2002). Some advice for fostering the identity-based commitment to the community (Ren & Kraut, 2012) is the demonstration of a name or a tagline which expresses the interest of the community. In addition to the above, some other steps for improving the identity-based commitment are the promotion of a common fate in which all the community members will benefit from a reward (Worchel & Rothgerber, 1998; Michinov, 2004), the clustering of similar members into homogeneous groups to avoid conflicts and turnover (Cothrel & Williams, 1999), and the members' anonymity (Postmes & Spears, 2005). The latter one may also encourage a greater level of self-disclosure than in the real world (McKenna &

Bargh, 2000; Newman et al., 2002; Emanuel et al., 2014) and form closer social bonds (Ellison, Steinfield & Lampe, 2007), increasing the bond-based commitment as well.

Moreover, in relation to the bond-based commitment, the creation of groups (Ginsburg & Weisband, 2004; Zaccaro & Dobbins, 1989) and especially named groups (Ling et al., 2005; Kittur & Kraut, 2008) with named members (Ren & Kraut, 2012) within the community enhances the commitment to the whole community. The formation of subgroups and their control by subgroup management is also important as it reduces the information overload (Andrews, 2002; Maloney-Krichmar & Preece, 2005; Iriberry & Leroy, 2009). On the other hand, *bond-based* commitment can be reinforced when the members feel close to the other members. In order to succeed in this, the creator[s] can recruit existing social ties, people who are already friends with the members (Ren & Kraut, 2012), or exploit the feature 'friends of friends' as people like or are more trusting of people with whom they have shared acquaintances (Yuki et al., 2005). The members should use personal profiles for self-disclosure to increase attraction, such as photos, recent activities and interests (Walther, Slovacek & Tidwell, 2001; Yee, Bailenson & Rickertsen, 2007) which can have visible responses for communication (Ren & Kraut, 2012). In addition to the personal profiles, the members should have personal conversations in order to build relationships (McKenna, Green & Gleason, 2002) and increase the sense of co-presence (Slater et al., 2000). Sometimes, off-topic communication is preferred for enhancing the interpersonal interaction as research shows that restricted conversation makes the community less appealing to people who want to build stronger relationships with the other members (Postmes, Spears & Lea, 2002).

Normative commitment is associated with the commitment to the purpose of the community, the commitment of other members and the reciprocity. Therefore, highlighting the purpose and up-to-date success of the community and its members, is an effective way to remind the members why they had first joined the community. Beyond the self-normative commitment, a demonstration of others that feel an obligation to the communities along with what they have received by now, empowers that feeling to the rest of the members too (Ren & Kraut, 2012). Moreover, reciprocity, direct or indirect, activates the sense of obligation in the community

(Constant, Kiesler & Sproull, 1994; Wasko & Faraj, 2000; Nowak & Sigmund, 2005; Oh, 2012). Consequently, people feel obliged to help people who had helped them or anybody just to “pay it forward”. The community should provide opportunities to the obliged members to return those favours (Ren & Kraut, 2012).

Continuance commitment is linked to the net benefits people gain from the community, such as information, social support, companionship and reputation (Ridings & Gefen, 2004). The benefits for joining a community vary across the types of the community and the members, as shown in the work of Riding and Gefen (2004). Therefore, the designers of the community should take into consideration the profile of members’ motivations in order to provide the appropriate experiences. This could be done by releasing survey instruments to assess motivations for participating in an online community (Ghosh, 2005; Nov, 2007). Assessing motivation for participating in online communities will be discussed in-depth in Section 2.6.1.

Research that studies the impact of community commitment on participation in online communities suggests that each form of community commitment is associated with different online behaviour by the members and has unique explanatory power (Bateman et al., 2010). For instance, the outcomes of the research show that affective commitment is the only form that significantly predicted reply-posting behaviour.

2.5.5 Transformation

Once the community reaches this stage, it can take several paths; sustain itself and continue to grow or stop existing, leaving maybe a legacy behind. Regarding the latter, Wenger et al. (2002) explain that the domain may no longer be relevant or interesting, the community may merge with other communities, the community may have become too complex to make sense, or the work of the community may have finished. In those cases the natural evolution of the community is to leave a legacy behind. Some other times it loses the will to sustain. Research indicates that many visitors to online communities reduce participation because of ‘lack of interesting people or friends’ or ‘non-interesting content’ (Brandtzæg & Heim, 2008).

Despite the inevitable turnover, the community should recruit successive generations of new members to survive (Kraut et al., 2012). Kraut et al. (2012) suggest that the central challenge for the community is to keep the newcomers around; the old members could have welcoming responsibilities (e.g. with personalised messages) and they should encourage the newcomers to reveal themselves, either with a profile or in a discussion thread, and finally they could become their mentors in how to behave and contribute. Moreover, a 'reader-to-leader' funnel (Preece & Shneiderman, 2009) is a good technique which causes progressive commitment as the newcomers may finally move from being readers to have a leadership role within the community.

Resnick and Konstan (2012) distinguish a number of approaches to convey trajectories of growth in membership and activity by displaying the appropriate indicators of growth, raising the success expectations and reducing the potential of community turnover. If the number of memberships and content is big, then emphasising this number motivates more people to join as it shows a higher probability that the community is reaching its critical mass. When the community is slow and slow growing, then it is better to acknowledge individually each new member and contribution instead of showing numbers. In the case that the community is small but growing fast, then displaying percentage growth is the best trajectory. Finally, if the community has already reached its critical mass, which is more likely in this stage of its life-cycle, then screening the absolute numbers is the best signal for the success of the community.

Although there are suggestions available in every stage of the life-cycle for sustaining the community, the communities never "run themselves", even if the fundamental design has been set in motion from the early first stage of its development; community leaders interviewed (Stuckey & Smith, 2004) argue that a community is never completely "built" and research shows that ongoing design and development depends on the individual community and its own community life (Engeström, Engeström & Suntio, 2002; Fischer, 2002).

High attrition rate in PPSR projects has sparked more research on factors that draw and sustain users in a project (Nov, Arazy & Anderson, 2011; Ponciano & Brasileiro, 2015). Accordingly, recent

research on online communities focuses on how the design can trigger user behaviour and how to evaluate the influencing factors (Fiedler & Sarstedt, 2014). Furthermore, open online communities are of particular interest as they share several features with PPSR communities (open data, peer production and open participation) (Robson, 2012; Wiggins & Crowston, 2012). The next section aims to gain insight into the motivation, level and type of engagement from empirical studies in online communities of any type (open, PPSR, Social Network).

2.6 User Motivation and Engagement

Studies of user engagement emphasize the behaviour of volunteers who invest personal resources such as cognitive power, physical energy and time, in order to help someone do something (O'Brien & Toms, 2008; Lehmann et al., 2012). User engagement has also been considered as a fundamental challenge of crowdsourcing projects (Doan, Ramakrishnan & Halevy, 2011). According to Howe (2006), in crowdsourcing applications (a) users are producers, not only consumers, (b) the number of participants is undefined and may range from one to several thousands and (c) users contribute towards a specific task, 'an open call', rather than spontaneously. Studies of user engagement in crowdsourcing projects indicate that engaging people in somebody else's problem through the internet is a challenge (Brabham, 2008).

A recent systematic review of methods for researching engagement in online communities by Malinen (2015) shows that behavioural patterns and user type identification have been analysed through activity logs; experience, motivations, values, needs and user roles through qualitative techniques; and change in user behaviour over time through observation and field research. The review included a total of 83 journal and conference articles, published in the years 2002-2014 from online academic research databases, including together the phrases "online community" and "participation". Most of the reviewed studies (64%) applied quantitative methods, with Social Network Analysis included; 20% mixed methods and 16% qualitative methods.

2.6.1 Motivation and sustaining participation

Research on Human Computer Interaction and principles stresses the importance of the design elements for attracting and engaging users in PPSR projects (Kim et al., 2011; Wald, Longo & Dobell, 2015) and other online communities (Burke, Marlow & Lento, 2009; Ren & Kraut, 2013). An in-depth study by Ren and Kraut (2013) on managing online conversations argues that communities are often less successful than they could be as many design decisions are driven by intuition, and trial and error instead of being based on the systematic understanding of users' motivation and contribution. For instance, results of this research regarding motivations suggest that personalised moderation increases members' commitment and contribution as users view different messages matched to their personal interests.

An example of an open community is Wikipedia, a wiki-based system that allows users to contribute to online articles. Regarding the motivation of Wikipedia members, Nov (2007) found that the top reasons for contributing to Wikipedia were "ideology" and "fun" and the latter was correlated positively to the number of contributions. For open-source software communities, although they are ideologically centred on the open access to software, contributors are often driven, beyond altruism, by motives of reputation (Lakhani & Wolf, 2003). A reason behind this is the review system that only allows highly rated software to be released (Oreg & Nov, 2008).

Findings of research in PPSR also agree with these non-altruistic motives. Rotman et al. (2012) in their research used the framework of four motives for community involvement (Batson, Ahmad & Tsang, 2002). They investigated the initial and on-going motivational factors affecting both scientists' and volunteers' commitment to citizen science projects. Results reveal 'egoism' (gain scientific knowledge, leisure, etc.) as the main factor for 80 volunteers to get involved with a project. Factors influencing their on-going commitment were initially 'being recognised for their contribution' and later on altruism. The egoism factor however is in contradiction to previous (Anderson, 2004; Holohan & Garg, 2005) and later research (Raddick et al., 2013; Curtis, 2015) that shows altruistic factors playing a prominent role in people's engagement. However, it

matches with a study exploring motivations in the Galaxy Zoo project that attributes to volunteers more egotistical rather than altruistically engagement motivations; 46% of users were interested, enjoying and wanted to learn more about astronomy) (Raddick, Bracey & Gay, 2010).

The 62 scientists in the Rotman et al. (2012) study were initially involved for more egotistical reasons, such as collecting data and in extension furthering their research career. Thereafter, they indicated altruism (providing public science, etc.) as the second most important factor. This result agrees with Curtis (2015) who indicated that ‘data collection’ and ‘help with scientific research’ are primary motivations for scientists to participate. Some secondary motivational factors were collectivism (increase the welfare of a group) and principlism (upholding of some moral principles) (Rotman et al., 2012).

Theory on motivations and contribution (Haythornthwaite, 2009) proposes that intrinsic motives are linked to a greater number of contributions and longer stay in the community. This hypothesis is verified by the research outcomes of the Old Weather project (Eveleigh, Jennett & Blandford, 2014) where members with intrinsic motives had increased and longer participation. Similarly, the participants in Stardust@home²⁰ with intrinsic – specifically collective – motives indicated enhanced participation frequency (Nov et al., 2011).

Some techniques to motivate users to join and remain in the community may involve a ‘reader-to-leader’ framework (Section 2.5.5) as in Wikipedia or other game-like mechanisms (i.e. Foldit) (Nov et al., 2011). Multiple ways for a member to participate has also been suggested by Bonney et al. (2015) as a way to satisfy diverse motives and sustain the interest in the community. Furthermore, it is suggested that finding ways for members to interact, such as comments and forum posts, and even communication through social media pages, improves the sense of community and the level of participation (Jennett et al., 2013; Jennett & Cox, 2014).

²⁰ PPSR project where participants search images of the aerogel (from Comet Wild 2) for signs of inter-stellar star dust

In some cases engagement techniques fail and some users may leave the community. One disengagement reason which was encountered in both Old Weather²¹ (Eveleigh et al., 2014) and Bentham²² (Causer & Wallace, 2012) projects is user anxiety due to low confidence about their contributions. Techniques that may prevent this type of disengagement and sustain participation in the community may be regular contact by the project leaders (Wald et al., 2015) by blogging for the community as in the Snapshot Serengeti project (Cox et al., 2015), or providing personalised feedback (Eveleigh et al., 2014).

Finally, the level of motivation was found to play a significant role in sustaining PPSR projects, with the less motivated users leaving the communities (Eveleigh et al., 2014). However, as Nov et al. (2011) assess, enhancing participation frequency may not enhance contribution quality necessitating further research on the effects of motivation and the types of engagement.

2.6.2 Behaviour and types of engagement

Research on participants' behaviour in Old Weather, clusters the users into two types: 'high contributors' and low contributors, or 'dabblers' (Eveleigh et al., 2014). The first group includes the small proportion of participants who are socially engaged and competitive. The second group contains the participants who remain in the project for a short period of time without getting involved socially. This classification of users falls closer into the 'active' and 'passive' participation (Malinen, 2015); other studies employ more complex analyses of users' participation, with more behaviour categorisations.

Research on YouTube consumption has indicated users to be mostly passive, with a small proportion participating actively and an even smaller proportion interacting with others (Shoham, 2013). The consumers are categorised in three types: 'active', 'interactive' and 'passive'. Active consumers comment on the videos without interacting with others in contrast to interactive consumers, and passive ones view the content similar to television. Nevertheless, this research

²¹ PPSR project that involves the transcription of archived Navy weather logs in teams

²² PPSR project that involves the transcription of the manuscript papers of the philosopher Jeremy Bentham (1748-1832)

does not include information about the producing users. In contrast, users in Wikipedia assume different roles in the system, according to the activity they perform, engaging in different ways and collaboration patterns with the system and contributing in differing ways to data quality (Liu & Ram, 2011).

Open educational resources and courses have also raised the need for exploring patterns of learners' engagement and disengagement in learning communities. Research into the motivation of informal learners on The Open University OpenLearn platform categorises the users into 'volunteer students', 'social learners' and 'casual users' (Godwin & McAndrew, 2008), where the first group is more interested in the content and the self-assessment tools, the second group prefer to learn through their interaction with other people by using communication tools and the third comes across the content while searching on the internet.

Study on the level of engagement and behaviour of users in citizen science projects (Galaxy Zoo and Milky Way Project) clusters the participants based on participation metrics such as daily devoted time, relative activity duration, and variation in periodicity ratios (Ponciano & Brasileiro, 2015). The resulting engagement profiles are 'hardworking', 'spasmodic', 'persistent', 'lasting' and 'moderate'. Although this study provides insight into measuring the level of engagement and characterises the users, it neglects the social engagement aspect and the psychological factors lying behind those engagement profiles.

Finally, another method for measuring the level of engagement is the overall contribution by the members. A report for iSpot project has focused on the volume of engagement and the outcomes of overall contribution. iSpot has over 31,000 registered users who have added more than 200,000 observations with over 340,000 images, identifying more than 6,900 different species and has also contributed to the identification of two species previously unrecorded in the UK (Scanlon, Woods, & Clow, 2014).

User motivation has been studied in the context of the life-spans of communities. The findings from a community of breast cancer patients indicate that over time the participants shift from

being 'seekers' to becoming 'givers' of information and start to benefit others (Rodgers & Chen, 2005). In contrast, a study on Everything 2 (Velasquez et al., 2014), a user-generated encyclopaedia similar to Wikipedia, shows that users become 'latent' over time and contribute and communicate with others less. The participants, however, do remain active but more selective with their contributions. This may be related to a final measure for engagement that focuses on the users' identification with the community (Vreede et al., 2013).

2.7 Summary

The importance of science literacy in promoting cultural values and supporting modern technology-based economy has been endorsed as an essential component of a democratic society. This has led to the development of several participation models and projects that aim to engage the public with science and promote scientific understanding. Involving participants in scientific research employed the establishment of projects with a variety of tasks and projects goals. A number of projects focus on the informal education of citizens; some others exploit the computer or cognitive power of the public for producing more science. Studies have been mainly looking at how to evaluate and improve the scientific outcomes, leaving in the background actions for enhancing the learning outcomes and the role of citizens within the projects.

IBL has also been proposed as a method for enhancing science literacy as it can engage the learners in all the stages of scientific inquiry while advancing scientific thinking. A more recent approach to IBL introduces authentic scientific research and personally meaning activities in order to place science in the real world and enhance the commitment arising from learners' personal interest. IBL has mainly been applied to school settings.

Citizen Inquiry is an approach to informal science learning which combines aspects from IBL and PPSR models and aims to engage citizens in online communities of scientific investigations. Citizens within Citizen Inquiry conduct their own research based on their everyday science experience and supported by science experts and inquiry tools. As in other citizen participation projects, there is need for further investigation regarding the engagement and scientific/learning

outcomes of Citizen Inquiry communities. In this PhD research the investigation starts with an exploratory research question which is looking at the main components of Citizen Inquiry (motivation, inquiry, collaboration, mentoring, software and experience) and it is summarised as follows:

“How can citizens engage in inquiry-based learning through peer collaboration and mentoring by experts without formal instruction?”

The outcomes of this first design study (Chapter 4) lead to a second more extensive design study (Chapter 5) that aims to improve the participation and sustaining of the community. Active participation has been considered essential for sustaining online communities and for this reason has become a popular research topic. Current research explores how to create and sustain online communities, but also investigates the different ways participants engage. Exploring engagement and participation has also been acknowledged by citizen participation projects, leading to studies exploring the motivations, levels and types of engagement in such online communities. The acquisition of new knowledge on online community creation and sustaining resulted in the development of a new research question in the second design study as follows:

“How can we create an active and sustainable online community for citizens to engage with online scientific investigations?”

The final research question involves the exploration of new community aspects applied to the second design study: creation and sustaining of the community (RQ1) and member engagement (RQ2), but also persists in investigating the science learning that happens within the Citizen Inquiry projects (RQ3).

Chapter 3: Research Methods

3.1 Introduction

This chapter focuses on the methodological approach used in this thesis and the research methods used toward the exploration and evaluation of the research questions. It discusses how design-based research and a mixed methods approach were applied to this research, repeats the research questions of each design study, presents the general data collection analysis methods and indicates how these methods were implemented in each design study. Finally, it informs about the ethical considerations taken into account for the design of this research, and how validity and reliability of the outcomes were verified. For the approaches used in creating and developing the online communities see Chapter 4 and Chapter 5.

3.2 Design-based research

The current PhD study employs a design-based research (DBR) methodology (Design-Based Research Collective, 2003; Collins, Joseph & Bielaczyc, 2004; Wang & Hannafin, 2005; Bell, Hoadley & Linn, 2013). DBR emerged from the need for educational research to be attached to the issues of everyday practice and it leads to the development of usable knowledge. As Barab and Squire (2004, p. 3) explain *“Design-based research [...] was introduced with the expectation that researchers would systemically adjust various aspects of the designed context so that each adjustment served as a type of experimentation that allowed the researchers to test and generate theory in naturalistic contexts”*.

DBR stresses the need for design principles that inform and enhance both research and practice in educational contexts. It was designed by and for educators with the aim of improving education research practices. Cobb et al. (2003) compare DBR to philosophical orientations for education (e.g. constructivism) and argue that the latter ones often fail to provide detailed guidance in

organising instruction whilst referring to DBR as a “*theory that works*”. DBR should refine both theory and practice (Collins, Joseph & Bielaczyc, 2004).

The aim of the design is to overcome a problem or create an improved practice and the ‘intervention’ is a collaborative task of both the researcher and the participants (e.g. practitioners, learners) (Cobb et al., 2003). A criticism against DBR is that it is not as rigorous as experiments, and hence the results of each iteration may not be valid (Hoadley, 2004). Therefore, there are many questions such as whether an intervention that researchers do not entirely control can be characterised adequately, and whether the results can be implemented in another context. An advantage over some other methods – that comes from being intimately involved in the research – is the development of a better understanding of the research context (Cobb et al., 2003).

Furthermore, DBR allows the researchers to study interventions, change the educational practice with ongoing revisions according to current success, involve other researchers in the design, investigate many different aspects not a number of hypotheses, and identify all the aspects that may affect the situation rather than manipulating specific variables (Collins et al., 2004).

The design intervention may be of many types, such as a technological or activity intervention. The creation of the design in DBR begins with the evaluation of the specific context alongside investigations of relevant literature, and theory and practice from other design cases (Edelson, 2002). The four phases of DBR according to Reeves (2000) are:

1. Analysis of practical problems by researchers and practitioners
2. Development of solutions with a theoretical framework
3. Evaluation and testing of solutions in practice
4. Documentation and reflection to produce ‘design principles’

A significant feature of DBR that contributes to its validity is the real educational context which allows the results to be used effectively to inform and improve practice (Wang & Hannafin, 2005). Real-world settings, such as realistic technological and personal support within the intervention,

are important for its effective transfer to other contexts (Brown, 1992). According to Jan, Chee and Tan (2010), the quality of the results and the success of interventions depend on the alignment of domain knowledge presentation, frameworks for learning, affordances of the instructional tools and contextual limitations.

For this PhD research, an investigation of the current theories and issues around PPSR and other online communities is described in Chapter 2 together with some methods and outcomes regarding the issues. These have provided ideas for developing a theoretical and methodological framework. This framework, tested in real-life settings, with its evaluation and documentation in practice are demonstrated in the following chapters.

Another main feature of DBR is the involvement of multiple iterations of design, implementation, analysis and re-design (Cobb, 2001; Design-Based Research Collective, 2003). The outcomes of the first design provide the framework and the focus of investigation for the next cycle of iteration (Cobb et al., 2003). Moreover, researchers can be flexible with the ongoing design, but consistent with important principles of the design (Scharwitz et al., 1999). Thus, they can improve the design of the current iteration with on-going changes. This PhD research employed two design studies which were implemented to achieve a goal and answer the research questions. The first intervention design had a more exploratory character and thus allowed room for improvements in the design of the second longer iteration.

Researchers in DBR document all the aspects that are involved in the design and implementation of the intervention (e.g. time, commitment) for future re-use in similar contexts. They analyse the order and the relationships between the principles so that they will be useful in new settings (Brown & Campione, 1996). This guidance helps to facilitate the adaptability and generalisability of the research (Wang & Hannafin, 2005). The documentation for the first intervention can be found in Chapter 4 and for the main study in Chapter 5 and Chapter 7.

Adopting a DBR approach in this PhD research helped to evolve design principles for creating and sustaining online communities for people to engage in scientific investigations. These principles

do not create grand theories that have equal influence in all contexts, but reflect the conditions in which they operate, and aim to enhance the solution implementation (Reeves, 2000).

Further, DBR is a methodology comprised of both qualitative and quantitative research. Mixed methods are utilised during the iterative research phases in order to analyse the outcomes and inform the re-design of the intervention (Design-Based Research Collective, 2003; Bell, Hoadley & Linn, 2004). Moreover, the tools and techniques may vary and evolve during the different phases of an intervention as new needs and issues emerge. This combinatory nature increases the “objectivity, validity, credibility and applicability” of the findings (Wang & Hannafin, 2005). This focusing of attention on the problem instead of methods, and the ‘free’ choice of pluralistic approaches that best meet the research needs resonate with pragmatic philosophy (Cherryholmes, 1992; Tashakkori & Teddlie, 1998). Pragmatism views truth as changing over time, and considers knowledge as being both constructed and based on the reality of the world that we experience and live in (Johnson & Onwuegbuzie, 2004).

3.3 A mixed methods approach

In order to address the research questions, feedback, attitudes and opinions were sought from the participants of the two design studies. Research on engagement in PPSR projects focuses on exploring qualitatively the psychological factors of engagement, such as motivation, satisfaction and frustration, and a quantitative estimation of the level of engagement of each user. In a review of methods for researching engagement in online communities it is argued that a combination of qualitative and quantitative data provide better understanding of the results, as quantitative studies lack interpretative data and qualitative research lacks generalizable large numeric data (Malinen, 2015). This PhD research adopted a mixed methods approach aiming to measure engagement in Citizen Inquiry projects quantitatively and qualitatively.

In a mixed methods approach the researcher combines research methods, techniques, approaches, language or concepts into a single study (Bryman, 2006; Creswell, 2009). The design process usually employs a mixture of methods, such as quantitative and qualitative surveys,

interviews, visual data, systematic observation, in order to address the research questions (Symonds & Gorard, 2010). This approach is acknowledged to be useful and important as it allows the researcher to draw on the strengths of qualitative and quantitative research and balance the weakness of both (Symonds & Gorard, 2010).

Numeric data deriving from quantitative research are useful for validating and testing theories which may be generalised under certain conditions (Sapsford, 2006; Bryman, 2012) whilst in qualitative research it is more difficult to test theories and generalise to other populations (Thomas, 2013). However, data in qualitative research are often collected in naturalistic settings, providing descriptions of people's viewpoints on phenomena and individual cases (Maxwell, 2012). In contrast, knowledge generated by quantitative research may not reflect the participants' experience and understanding (Silverman, 2006).

This PhD research uses mixed methods to enhance the validity and interpretation of the results. One of the procedures used is 'sequential explanatory design', which consists of two distinct phases: quantitative followed by qualitative (Ivankova, Creswell & Stick, 2006). The rationale for this approach is that the analysis of qualitative data explains the statistical results by exploring people's viewpoints (Rossman & Wilson, 1985). It can be especially useful for explaining unexpected results derived from quantitative study (Morse, 1991). The limitation of this design is the lengthy time to collect and analyse both.

In general, mixed methods require increased amount of time and cost to conduct a study (Bazeley, 2002). Furthermore, the researcher needs to have good knowledge of the multiple methods being used and skills to collect, analyse and interpret the results of the different methods. Yet, the description of the procedure should convey the results to readers that are not familiar with a number of the methods being used (Creswell, 2009). There is also a risk that the researcher may choose methods within their expertise rather than others more appropriate for answering the research question (Bryman, 2003). In this PhD research, the data collection and

analysis approaches were selected based on measures, instruments and methods employed successfully in previous research (see Section 2.2.4).

3.4 Overview

This section presents the research questions of each design study, and the general methods employed in this research for data collection and analysis. Several outcome measures and instruments suggested in the literature (Section 2.2.4) were employed in this thesis: duration of participants' engagement, number of visits, improved understanding of science content and process (Bonney et al., 2009), participation volume, members' satisfaction, belonging to the community, quality of relationships, patterns of the community (Malinen, 2015). The instruments for measuring and analysing the outcomes, include self-report questionnaires, self-reported knowledge, focus groups and documentation of participation (Bonney et al., 2009), interviews, observations and surveys (Bonney et al., 2009; Malinen, 2015), log data, Social Network Analysis and content analysis (Malinen, 2015) and cluster analysis (Ponciano & Brasileiro, 2015).

3.4.1 Research Questions

This research is directed toward addressing two sets of research questions. The first set (a) belongs to Design Study 1 and aims at the exploration of Citizen Inquiry (Table 4). The second set (b) has arisen after the evaluation and reflection on the results of the first design study and literature survey (Table 5). The data collection and analysis methods were set to address these research issues.

(a) Design Study 1 – Inquiring Rock Hunters:

“How can citizens engage in successful inquiry-based learning through peer collaboration and mentoring by experts without formal instruction?”

Table 4: Design Study 1 – research questions

<i>rq1: Motivation</i>	What motivated people to take part?
<i>rq2: Inquiry</i>	How do participants engage with the inquiry process and learning?
<i>rq3: Collaboration</i>	In what ways do the participants collaborate: which tools do they prefer to use and how do they interact?
<i>rq4: Mentoring</i>	What help do participants need and how do they make use of that help?
<i>rq5: Software</i>	How effective is the web-based inquiry environment in supporting engagement?
<i>rq6: Experience</i>	What kind of experience do people gain from taking part?

(b) Design Study 2 – Weather-it:

“How can we create an active and sustainable online community for citizens to engage with online scientific investigations?”

Table 5: Design Study 2 – research questions

<i>rq1: Online Community</i>	How can we create an active and sustainable online community for Citizen Inquiry?
<i>rq2: Engagement</i>	How can Citizen Inquiry engage members of the general public with investigations?
<i>rq3: Science Learning</i>	How can Citizen Inquiry participants adopt an inquiry process that follows good practices of science learning?

3.4.2 Methods of Data Collection

The following table (Table 6) summarises the general data collection used in each and both design studies. Further information about the use of each method in the design studies can be found in Sections 3.5 and 3.6.

Table 6: Data collection methods

Design Study 1	Design Study 2
Online focus group	Log files
System Usability Scale	
Investigations, Interviews	
Questionnaires, Researcher notes	

Online focus group: The focus group method (or focused interview) is a form of group interview in which interviewees are people who have been involved in a particular situation (Merton, Fisk & Kendall, 1956). As a focus group is something that occurs in interaction and discussion with others, it is considered to be more naturalistic than individual interviews (Wilkinson, 1998). Moreover, it facilitates the exposure of individual attitudes, feelings and beliefs through the interaction and provides a larger amount of information in a shorter period of time (Morgan, 1997). It includes semi-structured questions and in this research it was conducted through synchronous communication as this may enable oral communication, expression of more emotion and co-presence which intensifies online interactions (Stewart & Williams, 2005).

An online focus group was not used as a data collection method in Design Study 2 as Design Study 1 showed that there was not great demand for participation (Section 4.7).

System Usability Scale (SUS): On the SUS participants are asked to score ten items that are related to the usability of the software. SUS is characterised as a reliable tool for measuring usability as it can be used on small sample sizes with reliable results, it can distinguish usable

systems, and it is easy for participants to administrate (Sauro, 2011). SUS was chosen as it has become widely recognised and an industry standard.

In Design Study 2 the System Usability Scale was not used, as the questionnaire used in this intervention was lengthy and there was risk of participant dropout. Instead, a usability Likert scale question: *“with scale 1 (easy) – 10 (difficult), how easy did you find the use of nQuire-it platform?”* was added for the respondents to mark the point that corresponds to their opinion.

Investigations: The participants of both design studies were given the opportunity to conduct their own investigations in the context of this PhD research. All the investigations were available and accessible on the platforms, and they were analysed to provide further information about the inquiries and help in addressing research questions regarding the IBL and science learning.

Interviews: Semi-structured interviews were conducted with the participants in both design studies. Semi-structured interviews are usually preferred when the researcher has a fairly clear focus of the investigation rather than a general notion of wanting to do research on the topic (Bryman, 2012). The interviews were recorded, transcribed and translated when the interview was not in English, by the researcher. This practice helps to correct the natural limitations of memory and allows a repeated and more thorough examination of what people said (Heritage, 2013).

Questionnaires: Self-completion questionnaires are convenient as they can be completed at the time and speed that the respondents want (Bryman, 2012). One limitation is that the questionnaires can be read as a whole and the questions may not be independent or answered in the right order. However, this can be eliminated with the use of a web survey that decides the order of questions based on the previous responses, and by which the researcher can also send out reminders to those who did not complete it. This research employed online questionnaires. These were first piloted with a group of colleagues in a pilot study (Section 4.7) in order to avoid undesirable missing data because of poorly worded instruction, skipping questions, and questions that are not understood.

The participants in both design studies were invited to participate in the online questionnaires through their email addresses. The invitation included a log-in code or identification number with which to complete the questionnaire. This method prevented non-participants from completing the survey and tracked those who had not responded. Non-respondents were sent a reminder email after a two-week period and a final reminder a few days before the end of the survey.

Different types of variable were generated in both studies, from the responses of closed-ended questions, such as ordinal, nominal and dichotomous variables. These were analysed in SPSS statistical analysis software (Version 21) and represented by graphs, indicating means and standard deviations. The qualitative feedback from the online questionnaires has been subjected to either a thematic or content analysis. Thematic analysis has been used for the open-ended questions whilst content analysis has been employed for closed-ended questions which had an open field for the participants to fill in when a predetermined response was not appropriate.

Researcher notes: The researcher actively supported the interventions in all tasks, from the design of the studies and the creation of the community to the dissemination of outcomes. Moreover, the researcher participated in both communities as a participant and moderator, contributing to the projects as a member and intervening when appropriate for improving the settings of the design. As DBR requires a broad documentation of the interventions which presents the consequences of the design on the activity (Collins et al., 2004; Hoadley, 2004), the researcher was taking 'memos', notes as a memory aid.

'Memoing' is mostly associated with grounded theory, yet it is considered to be a valuable tool for all qualitative research studies (Clarke, 2003). Memos in this research were used to assure the preservation of the ideas (Glaser, 1978; Denise, Beck & Hungler, 2001). Memos engage the researcher with the data and their meaning to a greater degree. Moreover, they can help to clarify thinking on a research topic from the time a study is conceptualized, providing a technique for articulating perspectives about the field and the development of the design.

Therefore, memos provided snap-shots of the researcher’s thought processes for later reviews. In this way, the researcher understood what ideas led to several decisions and could reconsider previous thoughts (Birks, Chapman & Francis, 2008). Whilst some researchers have provided methods for writing memos, Charmaz (2006) argues that the memos should be written according to what works for the researcher. Thus, writing may follow a formal record of process and actions or a conversational style that reflects their thoughts.

Log Files: Access log files provide quantitative attribute data that are often used to evaluate a website’s usability and attractiveness (Fielding, Lee & Blank, 2008). This method has been used in Design Study 2 to address the community-oriented research questions.

3.4.3 Methods of Data Analysis and Visualisation

This section presents the methods used to analyse the data that derived from the data collection. The following table (Table 7) summarises which data analysis method was used for the collected data.

Table 7: Data analysis and visualisation methods aligned to data collection methods

Data analysis methods	Data collection methods
Thematic analysis	Interviews, focus group, open-ended questionnaire responses
Content analysis	Open-ended questionnaire responses
Graphs	Closed-ended questionnaire responses, log files
Social network analysis	Log files
Quantitative metrics	
Clustering	
Chi-square tests	Closed-ended questionnaire responses

Thematic analysis: The analysis of the focus group, interviews and some open-ended survey questions focused on examining themes within the qualitative data and so thematic analysis was used (Guest, MacQueen & Namey, 2011). The analysis goes through the six phases of thematic analysis (Braun & Clarke, 2008):

1. Familiarization with data
2. Generating initial codes
3. Searching for themes among codes
4. Reviewing themes
5. Defining and naming themes
6. Producing the final report

For the interviews and the focus group, initially a transcription of the verbal content in the recordings took place. Social talk, activities (gestures, facial expressions), features of talk (emphasis, speed, pauses) and crutch words were not included as they do not add to the particular objective. Moreover, a colleague contributed to the transcription of more intelligible parts of the recording. Regarding the translation of the transcriptions when needed, the content was translated literally from Greek, with some exceptions where the meaning was interpreted in terms of the English language.

The analysis was a hybrid approach of deductive and inductive coding (Braun & Clarke, 2008) and theme development. Therefore, the interview themes focused on the data that were suggested by the research questions of each design study but at the same time themes linked to the data, giving new information, were identified. Also, a 'semantic' level analysis (Boyatzis, 1998) was followed, giving emphasis to what was said and the explicit meaning of the data without looking at the potential underlying ideas and assumptions.

A detailed read of the text took place, while making ideas for patterns of meaning that capture important elements of Citizen Inquiry deriving from the research questions (motivations, inquiry, collaboration, mentoring, community, engagement, software, experience). Then, the entire data set was coded through nVivo and the codes depended on the data; in some cases the content fell within more than one code. The list with the different identified codes was sorted into the potential themes, which mainly emerged from the overall research questions that drove each of the two design studies. If codes did not work in one of the already existing themes, a new theme was created.

The potential themes were reviewed in order to confirm whether they included the entire dataset and there were enough (and not too diverse) data to support them. For the review, all the collated data extracted for each theme were read to make certain they formed a coherent pattern for the theme. Next, the data set was re-read in order to ascertain that data missed in previous coding stages were coded and categorised in the potential themes. Finally, the themes were considered to be sufficient when the content and the scope of each theme could be clearly defined and each theme could “tell a story” about the data. The final report includes a narrative that describes the data and can support the research questions.

Although thematic analysis was a flexible method which allowed a range of aspects to be said about the collected data, the danger of poorly conducted analysis was taken into account as it may have influenced the aspects of data the researcher should focus on (Braun & Clarke, 2008). Therefore, at the end of the thematic analysis, the researcher revisited the research questions and looked for aspects that would help in addressing them. Another disadvantage of a simple thematic analysis is that it does not allow the researcher to make claims about the language used. However, this thesis does not investigate the use of language in the surveys.

Content analysis: The exploration of the investigations went through content analysis of the investigations conducted by the participants, available on the platforms. Content analysis is usually referred to as quantitative analysis of qualitative data (Morgan, 1993) and it is considered

to be a flexible method for analysing text data (Cavanagh, 1997). For the open-ended questions in the questionnaires the analysis is described as inductive category development (Mayring, 2000). Hence, the researcher did not use preconceived categories, but instead allowed categories to emerge from data (Kondracki, Wellman & Amundson, 2002). The textual data was explored inductively for emerging categories that relate to the same central meaning (Graneheim & Lundman, 2004; Elo & Kyngäs, 2008). Then, an initial list of codes was produced which was examined for any obvious grouping constructing a more concise coding frame. These countable coding units were analysed quantitatively, illustrating the importance of each code.

Graphs: Pie charts and bar charts were used to visualise statistical data in both design studies. A pie chart is a circular statistical graph divided into slices where each slice represents the part of a total value with a numerical proportion. Pie charts were used to illustrate closed-ended questionnaire responses, with only one parameter. Bar charts were selected over other data presentation methods since the height of the different bars represents each value in an easy way to display and compare two or more parameters derived from closed-ended questionnaire responses, log files and quantitative metrics.

Social network analysis (SNA): For the exploration of the interactions through the collected log data, an SNA approach was taken. SNA can be used in the context of learning to explore and promote collaborative links between the learners and the resources, in order to help them develop their capabilities (Haythornthwaite & Laat, 2010). The analysis of the structure of social networks of informal learning networks, such as educational blogs, has also been featured in the past (Pham et al., 2012). SNA conceptualizes individuals or resources as nodes, which are connected by ties if a link (e.g. interaction, contribution) exists between two nodes (Wasserman & Faust, 1994).

Quantitative metrics: For the evaluation and measurement of the online community activity, researchers have developed success metrics. Metrics are applied to log data and are used to compare online communities, and measure the impact of adding design components to them

(Iriberry & Leroy, 2009). In this research, quantitative engagement metrics produced by Ponciano and Brasileiro (2015) were used to compare two contributory citizen science projects with a community where members were allowed to have ownership over the investigations.

Clustering: Connectivity and centroid-based clustering of the quantitative metrics were used to create clusters in such a way that the members in a group are more similar to each other than to those of other clusters (Kroenke, 2014). Clustering method was chosen in this research as an exploratory way to identify desirable user behaviours and investigate their properties.

Chi-square test: Chi-square tests measure the relationship between observed and expected representations in each set of variables (Aron, 2012) and for 2x2 chi-square tables it can be corrected by using Fisher's exact test or Yates' correction (Richardson, 1994). Chi-square analysis was carried out in Design Study 2 to explore the association between some of the nominal variables: belonging to the community and current activity status (see Section 6.3.7).

3.5 Design Study 1

The first design study 'Inquiring Rock Hunters' ran in May 2013 and aimed to involve members of the public in creating and conducting their own investigation on rocks (see Chapter 4). The main focus was to understand the engagement of citizens in online scientific investigations and thus, it focused on exploring the following aspects: motivations for participating in a Citizen Inquiry project, inquiry, collaboration between the participants, mentoring by the experts, the effectiveness and usability of the inquiry software, and what experience people gain from their participation. The main software used for the first design study was the nQuire platform which is described in detail in Section 4.4.

The following table (Table 8) shows an overview of the data collection methods and the particular objectives they are targeted towards. For Inquiring Rock Hunters project, Questionnaire A, System Usability Scale, investigations, online focus group, interviews and researcher notes were used for

the data collection. Under each one of the data collection methods there is the type of information they produced matched to aspects of each research question (Table 4).

Table 8: Design Study 1 – Inquiring Rock Hunters: data collection methods and objectives

	Questionnaire A	System Usability Scale	Investigations	Online focus group & Interviews	Researcher Notes
rq1: Motivation	Reasons for joining the project/ community				
rq2: Inquiry	Level of difficulty in forming questions Revising questions after feedback		Completed investigation/ quality of conclusions Methods used for data collection Type of data collected Type of questions non-experts ask Vocabulary	Easiest and most pleasant inquiry phases Experience of inquiry-based investigations	Interactions
rq3: Collaboration	Communication /Collaboration preferences			Use of communication tools	
rq4: Mentoring	Inquiry phases Geology knowledge and techniques Sources of help			Use of tutorials, video, instructions	
rq5: Software	nQuire tools: Effectiveness	nQuire tools: Effectiveness Usability Usefulness Desirability		nQuire tools: Effectiveness Usability Usefulness Desirability	
rq6: Experience	Gains from participating				

3.5.1 Investigations

The structure of the investigations was examined to check the completion status of every investigation and the completion status of each individual investigation phase. Then, some general statistics based on the total number of the investigations were calculated in order to quantify the text information. In addition, the methods used for data collection, the type of research questions formed, and the type of material and data collected in each phase were explored and categorised when possible.

Part of this checking process was also a vocabulary analysis, including:

(a) matching the vocabulary used in the investigations (one by one) with a geology-specialised vocabulary (Appendix A) to explore whether the participants adopted a field-specific language and

(b) looking at the type of the most used words in the investigations.

The qualitative data analysis software 'nVivo' (Version 10) was used to compare the two vocabularies. The geology-specialised vocabulary was contributed by a science PhD student and approved by a geology PhD student. The investigations' text as well as the geology corpus was imported into nVivo, where a function allows a count of geology words included in each investigation. The calculation returns the number of geology words found in total and the number of individual words found. For example, if the word "rock" were used three times in singular or plural, it is counted as the same word. In this way, a list with all the investigations and the number of geology terms used was created giving an opportunity for further comparisons between the investigations and further understanding of the way the Rock Hunters use the vocabulary in their investigations. Also having information about the participants' level of expertise from the Questionnaire A responses helped in the comparison of geology vocabulary used between the different groups (Section 4.8.2). Using another nVivo function, nodes were created with the most-used terms from all the investigations. Thus, there was a record of the words the participants prefer to use and there was opportunity to check whether these were geology oriented.

3.5.2 Online focus group

Participants in the first design study were invited to take part in a focus group with semi-structured questions (Appendix B) in order to provide some enriched qualitative information about the general design of the study and their satisfaction with the whole experience of the investigations, the tools and the other participants. The main aim of this method was to explore the experience and satisfaction of participants. Thus, the interactions within the group were focused on the experience of the interviewees with the investigations and the individual inquiry phases, and the use of nQuire platform, and other communication and guiding tools (e.g. chat, forum, tutorials, video).

The means of the online focus group interview was decided after a comparative study was made of some synchronous communication tools – tested with a group of two colleagues. ‘Hangouts on Air’ and ‘FlashMeeting’ were the tools having the most convenient features (URL sharing and recording). The next step was to decide whether a turn-taking tool (FlashMeeting) providing equity of participation was more suitable than a non-turn-taking tool (Hangouts on Air) which offers easier flow. Hangouts on Air was the final choice as the stop/start broadcast feature of FlashMeeting was a barrier to the easy flow of conversation required for the particular focus group. Some other tools were also tested out, such as Hall.com, meeting.10, emeet.me, sifonr, vidyoway, camdip, livecage, tinychat. These tools were rejected directly because they were considered not straightforward enough to be used by novices without detailed instructions. Moreover, some of them require signing up using email or/and have no recording option.

The participants were allowed to vote for their preferred date and time of the focus group. Due to the unavailability of the participants, only one focus group took place, transcribed and translated by the researcher, and then analysed through thematic analysis (Section 3.4.3).

3.5.3 Interviews

Although focus group (Section 3.5.2) was the predetermined method, interviews emerged as an alternative option for the participants who stated they were not available or willing to attend the

online focus group but still wanted to provide some feedback on the project's design. Thus, an invitation was sent out to all the participants and semi-structured interviews (Appendix B) were conducted with everybody that accepted the invitation, face-to-face or online (Facebook, Google Hangouts), according to the interviewee's preference. The individual interviews aimed to the same objectives as the focus group and were analysed through thematic analysis (Section 3.4.3).

3.5.4 Questionnaire A

Questionnaire A (Appendix C) was accessed online and hosted by Bristol Online Surveys (BOS). BOS is used by The Open University for Student Statistics & Surveys and it allows the development, organization and analysis of surveys via the Web. This particular online service was chosen over the popular "Survey Monkey" due to the BOS license provided by The Open University, which provides an option to add more than 10 questions for free.

All the participants (both expert scientists and non-experts) were invited to complete the questionnaire at the end of the project. It included eleven open and closed-ended questions aiming to address aspects of all the research questions (Table 8). Hence, it offered information about the motivations, inquiries, collaboration, mentoring, nQuire platform, and experience. The questionnaire included questions regarding the level of members' expertise, reasons for joining the community, how difficult it was to form research questions, and whether they needed to revise them. Also, whether they needed help and for what, where they looked for it and which inquiry phases were the most difficult. Furthermore, the participants had the chance to speak about their preferences and experiences in using the communication tools (forum and chat) and express their choices and satisfaction with the nQuire platform.

3.5.5 System Usability Scale

The SUS (Brooke, 1996) (Appendix D) was filled in by all the participants, experts scientists and non-experts, at the end of the project and was used to provide information about the software usability. The score for the SUS questionnaires which involves a Likert scale (1 to 5), is calculated based on the instructions in Brook's paper (1996). The SUS score was used in the analysis of the

nQuire platform and tools to reinforce the feedback given by the other collected data, as it gives information about the general image and perception of the participants on the usability of the nQuire platform.

For the SUS score, for questions 1, 3, 5, 7 and 9 the score is calculated as the scale position minus 1 (e.g. if a respondent chose “3” the score will be 2) and for the questions 2, 4, 6, 8 and 10 the score is 5 minus the scale position (e.g. if a respondent chose “4” the score will be 1). Then, the sum of the scores for all questions is multiplied by 2.5 to give the overall SUS score (Brooke, 1996).

3.5.6 Researcher notes

A result of the researcher being a moderator of the community in the first design study, beyond the support towards the participants and the project, was the use of the memos for the creation of an observational social network graph (Figure 23, Section 4.7) demonstrating the interactions between the participants. Hence, the graphs visualised when members communicated or collaborated on the forum, investigations or chat. Then, the interactions were further analysed based on observations on the type and level of communication between the participants.

3.6 Design Study 2

The second extended design study ‘Weather-it’ ran between November 2014 and February 2015 and aimed to explore thoroughly the engagement of citizens in communities of online scientific investigations (see Chapter 5). In this intervention, the participants had the option to create or join three types of investigations: Sense-it, Spot-it and Win-it (see Section 5.3.1). The main focus of this study was to investigate how to create active and sustainable communities of scientific investigations, how the members are engaged in the community and ways to improve the engagement, and finally how they learn and the ways to support science learning. The main software that hosted the study was the nQuire-it platform combined with the Sense-it Android app. (Section 5.3.1).

The following table (Table 9) shows an overview of the data collection methods in Design Study 2 and the particular objectives they are targeted towards. For Weather-it, Questionnaire B, log files, interviews and researcher notes were used for the data collection. Under each one of the data collection methods there is the type of information they produced matched to aspects of each research question (Table 5).

Table 9: Design Study 2 – Weather-it: data collection methods and objectives

	Questionnaire B	Log files	Interviews	Investigations	Researcher notes
RQ1: Community Creation and Sustainability	Recruitment Motivation Expertise Belonging to the community Current activity status Feedback on the design of the community	Community structure Interaction Sustainability	Reasons for dropping out Reasons for lurking	Overall participation Interconnection between the investigations	Sustainability Ongoing and future improvement
RQ2: Engagement	Participation Satisfaction Attitude Disengagement	Engagement metrics Engagement profiles		Feedback/ follow-up responses	
RQ3: Science Learning	Self-reported knowledge New knowledge (content, methods, other)	Activity profiles	Experience of investigations Feedback by experts Comparison of Design Studies 1 and 2	Investigation preferences Types of activity and learning Inquiry patterns Completed investigations Quality of conclusions (plots, ideas) Vocabulary	
RQ1: Community Software	nQuire-it toolkit: Usability Suggestions for improvement		Feedback on software	Calibration of Sense-it app.	

3.6.1 Investigations

Weather-it members were asked to create/join and conduct collaborative investigations. The data from the investigations were collected and analysed in order to provide information for the following:

Overall participation in investigations: The participation volume was calculated based on the number of registrations in the project, investigations, total memberships in investigations, created data, comments, forums posts and average members per investigation. In addition, a small description for each investigation was given to provide information for the type of investigation the participants were engaged with.

Patterns of investigation: Social Network Analysis (see Section 3.6.4.1) was used to demonstrate the interconnection between the co-joined investigations and type of investigations. Therefore, it provided information about which investigations or types of investigation tend to be chosen together. Furthermore, Google Analytics data identified the most visited and popular investigations.

Participation in individual investigations: The criteria for exploring each investigation differed according to their type (Sense-it, Spot-it, Win-it). For Sense-it investigations, collected data were counted, the data collection method was examined and the sensor measurements were analysed. For Spot-it investigations, total and identified pictures/inquiries were counted. For Win-it investigations, the proposed ideas were examined and in some cases assessed by weather experts, votes were counted, and the completion status was checked.

Type of activity and learning: Initially, the creation of activity profiles through cluster analysis (Section 3.6.4.3) was the predetermined method for exploring the activity and learning in the community. However, as the clustering was not feasible due to the diversity of activities members were involved in, all the types of activity were described with examples of members who became involved or had exceptional participation. Types and evidence of science learning were also sought within the various forms of action.

Inquiry patterns: The interactions through comments under every inquiry item were studied and then classified into categories based on their type and scope (e.g. mentoring). These categories represent patterns of inquiry interaction between and within science experts and non-experts.

Plots: The plots produced by the sensor recordings were examined to confirm whether the uploaded measurements were valid and the participants followed the instructions for data collection correctly.

Sensor measurements: The values were analysed to permit a description of the results in different geographical areas. Furthermore, there was a comparative analysis among recordings from different mobile devices in the same area and between mobile devices of the same brand. The average percentage difference and standard deviation between each pair of mobile devices used by the same people was calculated to provide some insight into the scaling between the sensors and to facilitate their calibration.

Vocabulary: In this study the vocabulary was not compared to a weather-specialised glossary, as the results from Design Study 1 showed that the Google Copy Paste Syndrome (GCPS) (Weber, 2007) prevents the credibility of the results (see Section 4.9.2). However, nVivo was again used in the same manner as in Design Study 1 (Section 3.5.1) in order to spot the most frequently used words. To this end, weather or science-oriented vocabulary could be detected. Furthermore, the creation of weekly word-cloud vocabularies facilitated tracking of vocabulary progress.

3.6.2 Interviews

The interviewees were selected based on 'purposive sampling' (Patton, 1990). Some of the participants had some characteristics of interest, such as outstanding participation/lurking, dropouts, expertise or had joined both studies. Therefore, an extreme/deviant sampling procedure (Teddle & Tashakkori, 2009) was employed as a type of purposive sampling for the selection of cases of interest which concluded with the selection of eight interviewees: one with outstanding participation, one lurking, two dropouts, two experts and two participants of both studies (Appendix E). The aim of the interviews was to give information about dropping out and

lurking reasons, provide insight into the experience of members with the investigations, gain some feedback from weather experts about the design of the community, receive feedback on the software, and finally allow a comparison between the two design studies by members who joined both.

As the participants felt more comfortable in communicating via chat, the means of the interviews was the Facebook messenger and for the busiest ones (science experts) by email. Although in email interviews there is loss of spontaneity, it is argued that it takes pressure off interviewees to respond quickly and allows them to provide considered replies (Bampton & Cowton, 2002). Seven out of eight invited members gave a positive response to the invitation; the member with the lurking behaviour rejected it due to time constraints. The interviews were analysed through thematic analysis (Section 3.4.3).

3.6.3 Questionnaire B

Questionnaire B (Appendix F) was hosted by 'Survey Monkey' to which the Open University had subscribed for a gold account. This allowed the creation of a questionnaire with more than 10 questions. In this study, it was preferred over BOS, as it was easier to be used for a larger number of people who are not Open University students. BOS does not generate separate survey links for non-Open University members and thus all the invitations would have been sent manually to each member as in Design Study 1, providing username and passwords. The larger number of participants in Design Study 2 in comparison to Design Study 1, led to choosing Survey Monkey over BOS.

At the end of the project, all the participants were invited to fill in Questionnaire B which included 41 open and closed-ended questions. The focus of this questionnaire was to gather information about the recruitment, motivations for participating, weather expertise, belonging to the community, current activity status, attitude and satisfaction, engagement and disengagement reasons, self-reported and new knowledge, and feedback on the design of the community and the software.

3.6.4 Log files

In Weather-it the detailed actions that occurred within the project were recorded and stored in log files that could be analysed as part of the evaluation process. Thus, data from 14 weeks (23/11/2014-1/3/2015) were exported from the nQuire-it database. The log files provided data for the community structure, the interactions between the members and the missions, the evolution of the community; these were processed through SNA or visualised via bar charts. Furthermore, the log data helped in calculating some metrics indicating the engagement/disengagement of the participants which, through clustering, produced engagement profiles according to their level of engagement.

3.6.4.1 Social Network Analysis

SNA (Section 3.4.3) helped appreciate the structure of the Weather-it community, the participation of members (who are active and peripheral participants), to understand the patterns of interactions between the members and the missions, and answer questions like who contributed to whose data.

Basic social network analysis metrics were also used, such as centrality degree, betweenness centrality, and weighted degree to give insight for the members who are in direct contact to others, lie in the middle of other members, and are the most active people within the community, respectively. Some of the findings are then supported and qualitatively described via data logs.

The SNA methodology has been applied to the interactions of the Weather-it community:

- Part I – Interactions overview: The members are represented as nodes in graphs demonstrating who-contributed-to-whom. A directed tie is present between two nodes if one member contributed to the data of another member. The contribution may be (a) membership in missions, (b) data to missions, (c) comments to missions or posts, (d) liking posts, and (e) posting to the forum. Figure 5 (left) shows an example of this. Member A contributed three times to Member B, Member B twice to Member C and Member C once to Member A. The size of the nodes corresponds to their degree centrality (the number of their

ties) and it means that the bigger the node, the more contributions the member received and sent. The ties are also weighted (thickened) according to the number of contributions from the one member to the other.

- Part II – Co-joined missions: The missions are represented as nodes in a graph demonstrating co-joined missions. An undirected tie is present between two nodes if one member has joined both missions. Figure 5 (right) shows members A, B and C joining Missions 1, 2 and 3.

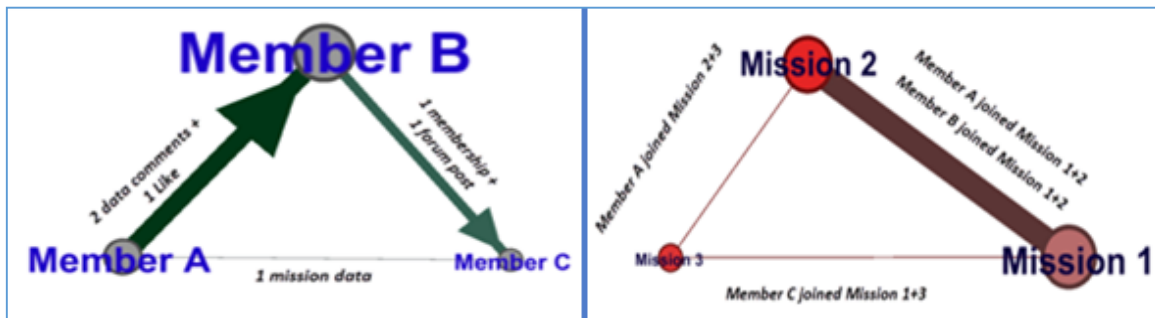


Figure 5: Who-contributed-to-whom example (left), co-joined missions by members (right)

- Part III – Community evolution: SNA approach was also taken for the exploration of the Weather-it evolution. Social network graphs should help appreciate the structure of the Weather-it community over time, answer questions like how the community has evolved and give insight into which reinforcement activities promoted that evolution. The ties represent the contributions between the members. The contribution may be (a) membership in missions, (b) data to missions, (c) comments to missions or posts, (d) liking posts, and (e) posting to the forum. The data was imported into Gephi in a spreadsheet and the generated network graph shows who-contributed-to-whom. A timeline of the graph alongside the weekly data recording were then used to split the evolution of the community into stages, based on the data trends.

The participants who registered for Weather-it but did not register with the nQuire-it platform were excluded from the SNA as well as the members who did not join any mission or forum topic as they were not able to create a tie in the network. Among the contributors there were some users who did not register with Weather-it and thus there was no access to their user ID and no

consent to use their data; those were also excluded from the network. Moderators (researcher and main supervisor) were also included in order to capture the contributions of members towards them. The data were then imported into the Gephi visualization tool in a spreadsheet, creating a directed network for part I and III, and undirected for part II.

3.6.4.2 Engagement Metrics

The metrics used for measuring engagement in contributory projects have been adopted from (Ponciano & Brasileiro, 2015), who applied them in measuring engagement in two contributory citizen science projects. Similarly to the work by Ponciano and Brasileiro (2015), only Weather-it members that had at least two days of activity are included in these metrics. Figure 6 shows an example of the timeline of a member during participation in Weather-it. The member may have had active days in the project (blue boxes) and during these days contributed with their data, comments, likes, forum posts and mission/forum creation. During a lurking day (red boxes), the member just visited the community without getting involved in any activity, than browsing. Finally, the black boxes represent the days of the project that the member did not visit the community. The number of days between the first and last active/lurking visiting day, show the total days the member was linked to the project.

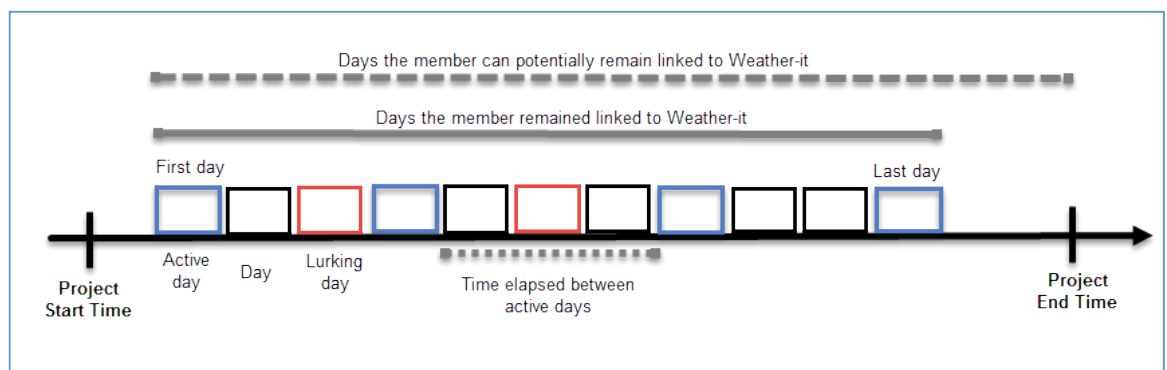


Figure 6: Timeline-example of a Weather-it member, with the days they visited (lurking, active) and did not visit the community

Therefore, the engagement metrics for each Weather-it member are calculated as follows:

Activity ratio: It is the ratio of days on which the member was active and executed at least one task in relation to the total days they remained linked to the project. The closer to 1 the more active a volunteer is during the days they are linked to the project.

Relative activity duration: It is the ratio of days during which a member is linked to the project to the total number of days from their joining to the end of the research project. The closer to 1 the longer a volunteer remains linked (persistent) to the project, from their joining to the end of the project.

Variation in periodicity: It is the standard deviation of the multiset of number of days elapsed between each pair of sequential active days (Figure 6). The closer to 0 the steadier the rate by which a volunteer returns to the project. For instance, if a member visited the community 1, 2, 15, 20, 22 and 28 of December then the multiset that standard deviation would be applied to is {1, 13, 5, 2, 6}.

In addition, the PhD researcher proposes the following metric for measuring lurking (not active contribution), based on research by Preece et al. (2004) on the extent of lurking in online communities:

Lurking ratio: It is the proportion of days on which the volunteer was lurking in relation to the total days they visited the project. The closer to 1 means the more a volunteer lurks (i.e. logs into the platform and browses content but does not contribute) during the days they are online.

Another metric used by Ponciano and Brasileiro is the 'daily devoted time' which shows the averaged hours a volunteer remains doing tasks on each active day. However, this metric has not been used in this study, as no reliable information on the login duration could be extracted from the nQuire-it log files.

3.6.4.3 Cluster Analysis

Clustering methods were used in order to produce engagement and activity profiles. The engagement profiles characterise the level of engagement of members that belong to the specific

profile. Activity profiles describe the type of activities the members that belong to a profile were interested in. Cluster analysis was made available via SPSS.

For the identification of the engagement profiles, the metrics' results were used and a clustering method similar to the one used by Ponciano and Brasileiro (2015) was adopted. Prior to the clustering the values of the engagement metrics were normalized in the interval [0,1]. Then, members were separated into two groups; active members (those who were active more than two days) and visitors (those with two or fewer active days). Active members were clustered based on the four metrics whereas visitors were placed in a different category in advance, and were clustered with 'Variation in periodicity' metric excluded, as it was not possible to calculate it with only two active days. The clustering outcomes were visualised through comparative bar charts that represented the engagement metrics of each profile.

For the identification of the activity profiles, a table was produced containing all the participants vertically and all the types of activity (data creation, comments, etc.) horizontally. Then, the table cells were used to indicate how many times a participant was involved in that particular type of activity. If there was not any involvement with a particular activity then the cell was equal to zero.

The following method was applied to both engagement and activity profiles clustering. A hierarchical clustering algorithm was used and a dendrogram was plotted to provide a suitable interval to test the number of clusters. The clustering quality was evaluated by Davies-Bouldin index (Davies & Bouldin, 1979) and Average Silhouette (Rousseeuw, 1987). Davies-Bouldin Index evaluates intra-cluster similarity and inter-cluster dissimilarities. The best clustering scheme has to minimise the Davies-Bouldin index (no cluster to be similar to another). Thus, the number of clusters for which the value is the lowest, is a good guide on how many clusters exist in the data. Average silhouette shows how cohesive the clusters are, with values close to -1 indicating poor clustering and close to 1 excellent clustering. A strong structure is found when values are between 0.71 and 1 while a reasonable range is between 0.51- 0.70 and a weak below 0.51 (Struyf, Hubert & Rousseeuw, 1996).

K-means was then utilised to classify the data through the number of clusters found through the Average Silhouette and Davies-Bouldin index. The a priori fixed clusters reduce the iteration time (Lu et al., 2008). K-means was preferred over a two-step method as the data did not include categorical variables with three or more levels (Norusis, 2007). The resulting engagement profiles were validated and described in combination with qualitative data of the participants that belong to each profile whilst the activity profiles were accompanied by exemplar-participants that fall into the particular profile. The qualitative data, collected from Questionnaire B (Section 3.6.3) included information such as level of weather expertise, current activity status, motivations for joining, attitudes towards the project, and satisfaction levels.

The creation of activity profiles, unlike the engagement profiles, was not successful as the members were mainly involved in diverse activities and not in a particular type of activity. Consequently, the community activity was illustrated through examples of activity and learning (Section 6.5.4).

3.6.4.4 Bar charts

Bar charts visualising data from the log files were created to summarise significant features related to the sustainability of the Weather-it community and represent them as a picture. Vertical bar charts were used to visualise the size of the data and facilitated the comparison among (a) weekly contributions and (b) active new and returning participants per week.

3.6.5 Researcher notes

In the second design study, log files replaced the observational analysis that took place in the first design study (Section 3.5.6) and thus, the researcher undertook a more administrative role, recording ideas such as thoughts, feelings and impressions, during the project that may later prove significant (e.g. for explaining the evolution of the community). Memos were recorded in a diary in the form of ideas for improving the designs and impressions on the ongoing outcomes. These memos were used as memory aids and were not intended to be shared publicly with the research participants.

3.7 Ethical considerations

Research involving online settings is increasing in prevalence, involving many forms and continuing changes. As a result, researchers are exploring ethical issues in forcing the researcher to evaluate issues related to methodological choices which are sometimes embedded in the tools' design (Burnett, Consalvo, & Ess, 2011). For instance, a question could be "does nQuire allow participants to use usernames, instead of their real names?". Thus, researchers when carrying out online and other studies should consider ethics issues, such as privacy, informed consent, confidentiality, risk, anonymity, ownership, recruitment, public versus private spaces (Buchanan & Hvizdak, 2009). Researchers of online survey studies should acknowledge the possibilities for participant identification when collecting data from online sites, and thus it is very important that these data are hosted at a secure place. Anonymity should be guaranteed and participants should be informed about the researcher recording their activities and which personal data are stored in the log files and used; these data should not be misused or get lost (Flick, 2009).

In this PhD research, after the settings of the online design studies were decided, favourable opinion to proceed was sought and given by the Open University Human Research Ethics Committee (HREC) (Appendix G and Appendix H). The application to the committee included description of the studies, information about research questions, recruitment methods, data collection and analysis techniques, consent forms and information sheets for the participants. The participants in the two design studies read the information sheets and signed the consent forms.

The collected data were deleted from any other locations (e.g. Facebook messenger) and hosted at a secure Open University server where they will be destroyed after the end of this research. Prior to the analysis of the data, the names members used on the platforms were changed to RH1 to RH24 in Design Study 1 (RH as Rock Hunters), and names inspired by clouds and winds in Design Study 2 (e.g. Cumulus, Zephyros). This activity was required as some members used their real names and may have been identifiable.

The participants were informed about the main findings of each project through email a few weeks after the end of the project.

3.7.1 Design Study 1 – Recruitment and consent

Research showed that the most important reason that people never join a research community is because they have never heard of it (Jamali et al., 2014). To this end, the researcher made strenuous efforts to publicise the communities. The advertisement design for Inquiring Rock Hunters included a leaflet (Appendix I) and text/invitations (Appendix J).

The first stage for the advertisement was to upload the relevant invitations to the Open Inquiry Learning blog (OIL) (blog created by the PhD researcher to provide participants with instructions and material) and opened up a Facebook web-page for the project (Appendix K). The second stage was to send out an invitation email to the Open University Department of Environment, Earth & Ecosystems (EEE) (Appendix L) and approach some expert geologists. The geologists were invited to the community as participants and not facilitators, but they were asked to provide help when needed.

The next stage was to release the advertisement to web-pages with visitors who are interested in Education (e.g. OU intranet), Geology (e.g. RocSoc) or citizen science (e.g. iSpot). The final stage was to obtain access to groups studying Geology; this target was realised by getting permission to enter several Facebook groups linked to OU modules in Geology. Table 10 shows the several ways and places the participants were recruited from.

After the invitations were sent out, a sequence of emails to the people who indicated interest in the project followed. The first emails included further explanations, important dates, information sheet explaining the project and a consent form (Appendix M). The latter one informed the participants about the aim of the project and provided instructions about their tasks within the project and the support they would receive.

Furthermore, the participants were informed about the purpose of Questionnaire A and focus group, and were asked to take part in them at the end of the project. Finally, they were given the important dates of the project and notified about how their data will be used. Then, invitation emails (Appendix N) to the nQuire platform were sent to the final list of participants. The PhD researcher in Inquiring Rock Hunters had a ‘facilitator’ and ‘helper’ role rather than participating in the project.

Table 10: Recruitment of Inquiring Rock Hunters participants

Facebook	Inquiring Rock Hunters
	SXG288 Practical Science: Earth and Environment
	S276 Survivors
	Open University Geological Society
	Bed, Bucks & Herts Geocachers
	RocSoc
Open inquiry Learning blog (OIL)	http://www.open.ac.uk/blogs/OIL/?p=6
iSpot	http://www.ispot.org.uk/node/325880
OU intranet	http://intranet4.open.ac.uk/blogs/askthecommunity/?p=718
RocSoc	http://openuniversityrocsoc.wordpress.com/
Email	Sci-EEE-All-List
	let-All-List

3.7.2 Design Study 2 – Recruitment and consent

For the enrolment of members (experts and non-experts), invitations were sent to communities related to learning, citizen science, citizen participation in science, weather as well as in Social Networks and mailing lists. Table 11 shows the several ways and places the participants were recruited from.

Table 11: Recruitment of Weather-it participants

Facebook groups	Weather-it
	Cloud appreciation society
	Hugh Miler's Birthplace cottage & museum
	British women pilots association
	Royal Meteorological Society (RMetS)
Email circulation	Tornado and Storm Research Organisation (TORRO)
	National Co-ordinating Centre for Public Engagement
	Public Communication of Science and Technology - Citizen science
	Science Department (OU)
	Centre of Research in Education and Educational Technology (CREET)
	Institute of Educational Technology (OU)
Web pages and forums	iSpot
	Royal Meteorological Society (RMetS)
	FLYER forum
	Open University Intranet
	Department of Primary Education forum (Greece)
	SciStarter
Courses related to weather	S141 Investigative and mathematical skills in science (The Open University)

In contrast to Inquiring Rock Hunters, the recruitment was continuous. The initial advertisement involved a leaflet (Appendix O) which included the aim of Weather-it community, the nQuire-it features and information on how to register. A later recruitment to other places was facilitated by

recipients of the leaflet, members of the core group and the community members. In addition, the information leaflets were circulated at conferences and other public spaces (e.g. The Open University).

In addition to the general advertisement there were also some personal invitations to expert meteorologists through the email. The initial emails were sent to expert members of meteorology communities and university departments. Then, some recipients became members of the community and/or invited colleagues to join by circulating the email-invitation.

Another effort for recruiting participants was the creation of a Facebook group 'Weather-it' (Figure 7) which promoted the activities within the community in order to attract new members. In addition, the hash tag #weather1t was used on Twitter for posts related to the project.



Figure 7: Weather-it Facebook group

The participants prior to their membership to the community they were invited to complete an electronic consent form (Appendix P). The form informed them about the aim of the project and asked for access to the number of missions joined or/and created, comments and data added, forum posts, number of shares and likes given/received. These data were also helpful for spotting

the top contributors, photographers and sharers every month. In addition, the participants were informed through the form about the dates of the project and how their data would be used anonymously in written reports, presentations and papers relating to the project. The participants were also asked to report their email address and username in order to be identifiable in the log files and available for contact.

Similarly, the respondents of the Questionnaire B were informed about the aim and conditions of the project and the duration of the survey. The respondents of both consent forms had to agree that they are over 18 years old, they understood the purpose and conditions of the research, and they voluntarily agreed to participate. Finally, the interviewees were informed that their answers would be 'recorded' and some of the interview content may be published anonymously.

The participants of both design studies were expected to have prior assumption. For example, those associated with the OU may well have assumptions about how forums are moderated, or availability of tutorial support, which could affect how they engaged with the learning, the social interactions and the technology. It was outside the scope of this PhD project to probe those assumptions and how they might affect engagement and performance, but that is a priority for further research.

3.8 Validity and Reliability

Validity is an important key to effective and worthy research and an important requirement for both quantitative and qualitative research (Cohen, Manion & Morrison, 2013). A mixed methods approach provides a strategy for 'cross-checking' (Symonds & Gorard, 2010; Bryman, 2012; Maxwell, 2012) where results from each method are used to co-found or confirm each other. This leads to methodological 'triangulation' that helps to reduce the limitations of every single method whilst avoiding distorting a researcher's picture of the particular piece of investigation (Cohen, Manion & Morrison, 2013). Artefacts generated from more than one method of collection with substantially the same results enhance the researcher's confidence in the validity of the research (Lin, 1976). Moreover, this cross-checking of generated data is further increased when the

methods are complementary (Cohen, Manion & Morrison, 2013), for example when the outcomes from the log files analysis correspond to those of the questionnaire.

In addition to a multi-method approach, there are also other types of triangulation used in this PhD research. The design studies were conducted within two different scientific spaces which each having its own culture (scientific language and methods). This 'space triangulation' with findings from diverse set of data informs about differences among the fields and overcomes the limitation of designing principles based on a single space (Smith, 1975). Another type of triangulation incorporated into this study is the combined levels of triangulation, drawing on individual and group analysis. Employing more than one level offers a more meaningful picture of the results (Cohen, Manion & Morrison, 2013). Finally, this PhD research uses 'investigator triangulation' (Silverman, 2006) for 'inter-coder reliability' in order to identify coding themes in both thematic and content analysis, and improve the reliability of the analysis (Carr et al., 2009), as this may be influenced by researcher bias (Bos & Tarnai, 1999). In each design study, the list with the codes was given to a colleague/qualitative researcher, who was instructed to apply the codes to a part of the data set (two interviews). Then, the analysis by the second researcher was compared to the analysis by the PhD researcher to see where their coding matched. For the assessment, the percent agreement was used, which is calculated by dividing the number of agreed coding to the total number of the code comparisons. An agreement of 75% has been achieved, falling into the 'rule of thumb' figure set at 70% (Guest et al., 2011).

In addition, trustworthiness in qualitative research can be addressed based on four criteria: credibility, transferability, dependability and confirmability (Shenton, 2004). 'Credibility' concerns the true picture of the phenomenon being studied and can be addressed by the familiarisation of the topic, the right choice of established research methods and the use of triangulation (Silverman, 2006). 'Transferability' can be possible by providing detailed contextual information about the research settings (Thomas, 2013). 'Dependability' can be addressed by providing thorough description of how the research was executed so that it can be repeated (Shenton, 2004). 'Confirmability' concerns the potential for research bias and thus the researcher should

demonstrate the emergence of findings from the data rather than their own predispositions (Guba, 1981).

Regarding research bias, the challenge for the researcher is to be aware of the potential sources of bias and consider them during the research process. Thus, this research has also been influenced by the background and beliefs of the researcher. For example, the researcher's background in education and the belief that learners should be a part of knowledge production and not just consumers has influenced the choice of this research topic. Also, the particular topics of the design studies were more familiar to the researcher, with the subject of the second study 'weather' being well known and of interest to the majority of people.

3.9 Summary

This chapter has demonstrated the principles of design-based research which is the methodology applied to this PhD work and then described the mixed methods approach used for the data collection and analysis. The general data collection methods used in this research were investigation text, focus group, questionnaires, interviews, log files and researcher notes. The general data analysis methods used to analyse the collected data were thematic and content analysis, graphs, social network analysis, quantitative metrics and clustering. Each of the design studies focused on particular objectives, and appropriate tools were used for collecting information in order to answer the research questions. Thereupon, additional information was given on how each method was applied to collect or analyse data, outlining ethical and methodological consideration during the research process. Then, the importance of validating the entire research process was emphasized. Further information about the settings of each design study follows in the relevant chapters, describing the design of each project and the explicit roles of the researcher and the participants.

Chapter 4: Design Study 1 – Inquiring Rock Hunters Settings and Results

4.1 Introduction

This chapter describes ‘Inquiring Rock Hunters’, the first design study in this thesis and a first approach to explore the participation of citizens in investigations about rocks through the Citizen Inquiry paradigm. In this chapter there is a survey of existing geology citizen participation projects, a description of the platform that hosted the rock investigations, the changes that were made to the platform, the project preparation, the pilot study and an overview of the collected data. As this design study was mainly exploratory and not very extended, this chapter includes a summary of the important findings relating to the basic themes (motivation, inquiry, collaboration, mentoring, software and experience). Then, it concludes with suggestions, based on this study’s findings, for the design of the next design study. In some of the descriptions, the participants are referred to as ‘rock hunters’.

4.2 Inquiring Rock Hunters

The ‘Inquiring Rock Hunters’ project (Figure 8) is an example of Citizen Inquiry as it allows adult citizens to run their own investigations in geology and gives them the opportunity to collaborate with geology scientists. This meeting of citizens with scientific investigation and with scientists took place on an online platform called nQuire (Mulholland et al., 2012) which supports the social nature of Citizen Inquiry and provides tools to support both the investigation and communication between the participants. The participants in this Citizen Inquiry were expected not only to be active during the whole project, but also to improve their understanding of science and develop practical skills of geology investigation.

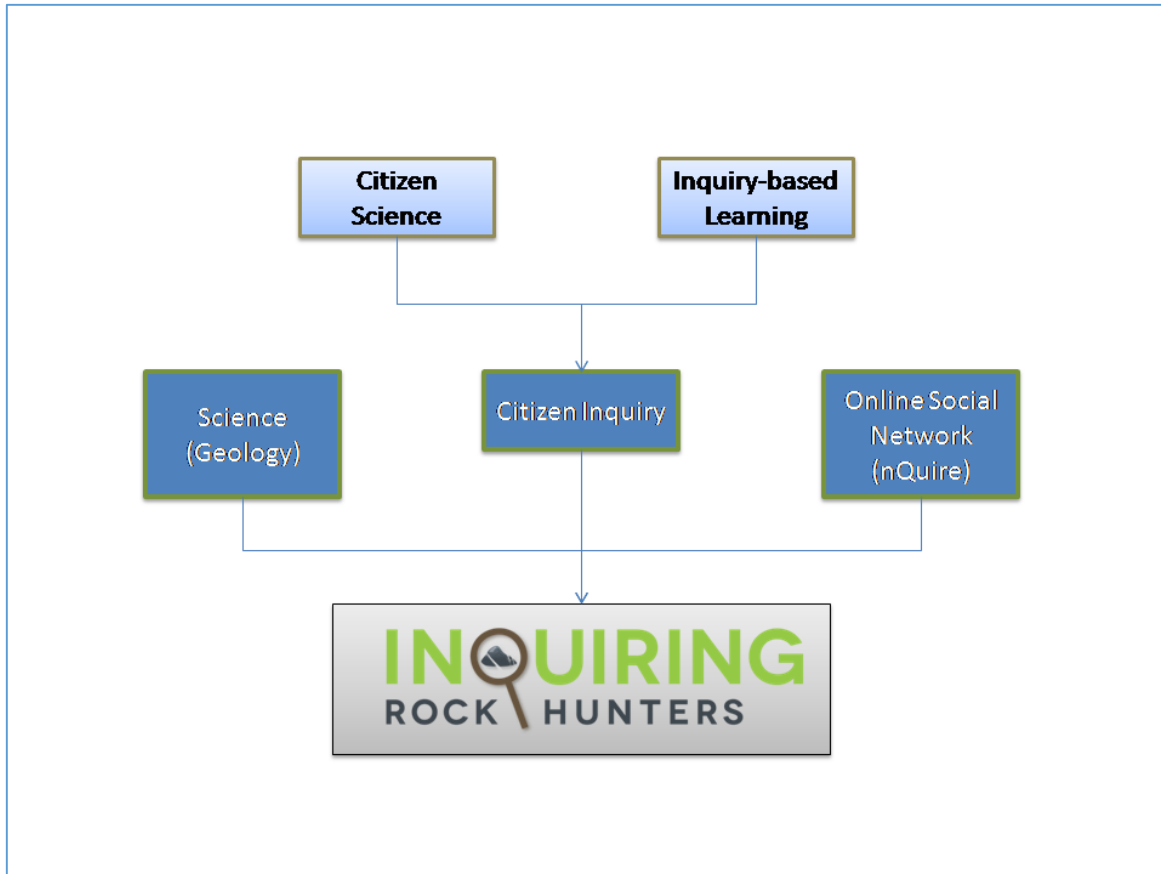


Figure 8: Inquiring Rock Hunters – a synergy of Citizen Inquiry, geology and nQuire

In this Section there is a description of some Geology citizen participation projects but it is mainly focused on GeoExposures (Powell, Nash & Bell, 2013) and Fossil Finders (Patel et al., 2011). These two projects are of different types: GeoExposures requires participants to observe and collect data while Fossil Finders includes the additional component of IBL which brings it closer to the ‘Inquiring Rock Hunters’ project. Although there are many citizen science and IBL projects (discussed in Chapter 2), this section covers citizen science projects on Geology exclusively, as Geology constitutes the theme of this design study.

Many people consider rock and fossil collection as an enjoyable hobby and they enjoy gaining more information about their findings. Citizen science projects on Geology provide citizens with ways to develop this interest in geology and at the same time contribute towards conserving a diverse geological heritage (British Geological Survey, 2015). The only prerequisite for taking part in such projects is an interest in geology, so people from all ages and levels of expertise get

involved in performing or managing the research-related tasks such as observation, measurement or computation.

A citizen science project on Geology developed and deployed by the British Geological Society is GeoExposures (Figure 9).

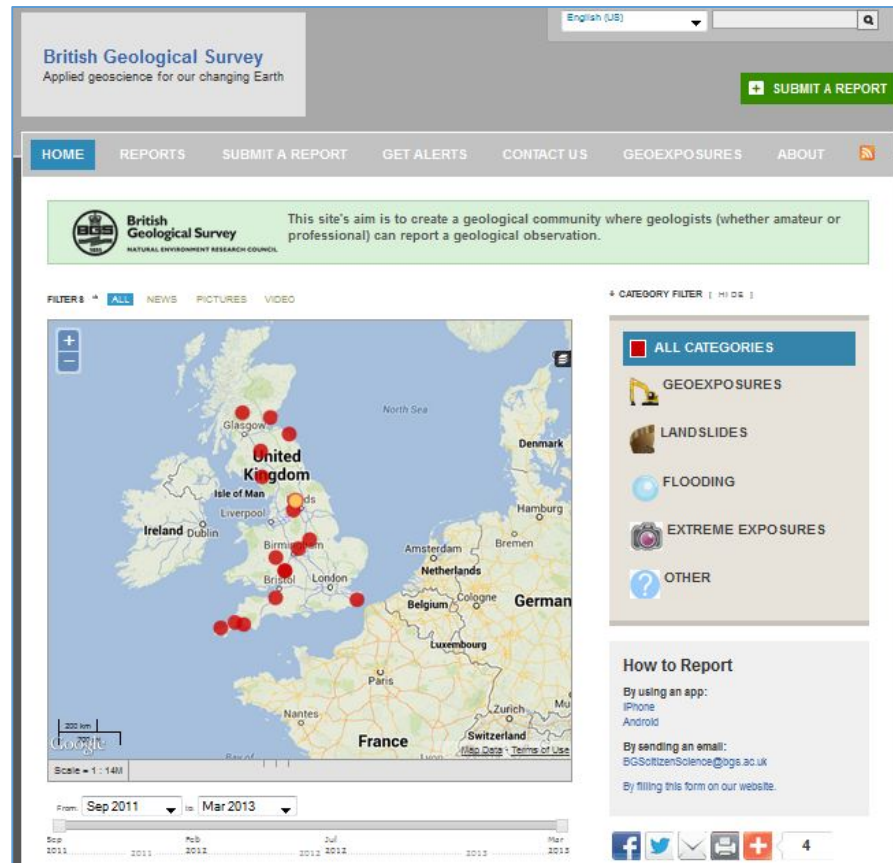


Figure 9: GeoExposures

Geoexposures²³ is a recently-developed crowd-sourcing project. Citizens participating in this project report and upload pictures related to a geological site to the web-site by using their smartphones or personal computers. The main aim of the project is to develop a record of the geological observations (i.e. geoexposures, landslides, flooding, extreme exposures) that might be otherwise lost to science (Powell, Nash & Bell, 2013). The web-site provides a proforma for adding the records, it enables picture uploading, and it is also supported by Google maps.

²³<https://britishgeologicalsurvey.crowdmap.com/>

The British Geological Society also offers a number of citizen science projects having as main tasks uploading photographs (EXTremeEXposures²⁴), reporting disasters (Report a flood event²⁵, Report a landslide²⁶), collecting samples (Volcano eruption ash collection²⁷) or adding observations (mySoil²⁸). Moreover, a School Seismology²⁹ project is available in which school children are taught how to detect signals from large earthquakes in the classroom by using a simple seismometer system and to exchange data with other schools.

Scistarter, similarly, makes available citizen science projects on Geology that involve citizens in gathering data/pictures (Geo-Wiki Project³⁰) mapping/gathering locations (OMEGA-LOCATE³¹), monitoring, etc. An interesting project found in Scistarter is Fossil Finders³².

Fossil Finders (Figure 10) is a collaboration between Cornell University and the Paleontological Research Institution (PRI) in Ithaca and it manages to combine a) authentic IBL within formal settings and b) collaboration among students and teachers with geology experts. It involves elementary and middle level students and their teachers in an authentic inquiry-based investigation of Devonian-aged fossils. The inquiry question for the project is given by the researchers as *“How did the organisms in the shallow Devonian seas change in response to environmental changes?”* and the students – guided by their teachers – have to identify and measure fossils in rock samples sent to their classrooms. The project attempts to involve students in learning about how science is done in the process of learning science content-matter (Fossil Finders, 2015). The project was a comparative study between control (5 control teachers, 239 students) and experimental groups (7 Fossil Finders teachers, 468 students). The Fossil Finders teachers had been through some professional development focusing on how to translate an authentic scientific setting to a science classroom with the inquiry approach. The duration of the

²⁴<http://www.bgs.ac.uk/citizenScience/EXposures.html>

²⁵<http://www.bgs.ac.uk/flooding/reportAFlood.html>

²⁶<http://www.bgs.ac.uk/landslides/report.html>

²⁷<http://www.bgs.ac.uk/research/volcanoes/GrimsvotnAshCollection.html>

²⁸<http://www.bgs.ac.uk/mySoil/>

²⁹<http://www.bgs.ac.uk/schoolseismology/schoolSeismology.cfc?method=viewLatestQuake>

³⁰<http://www.scistarter.com/project/690-Geo-Wiki%20Project>

³¹<http://www.scistarter.com/project/704-OMEGA-LOCATE>

³²<http://www.fossilfinders.org/>

project was two summers and it also included instructions on inquiry-based approaches, nature of science in general and aspects of palaeontology. The evaluation consisted of a Likert scale as pre and post-survey addressed to students, measuring mainly their interest in school science, and some follow-up interviews with teachers and selected students. After assessing the results, the importance of guidance in IBL was highlighted as it was found that the authentic investigation alone did not engender students' interest in science but the teacher's performance and the physical samples made the difference by emphasizing authenticity and sparking discussions (Patel et al., 2011).



Figure 10: Fossil Finders

The context of the Fossil Finders project has some aspects in common with the current PhD study as it contains the exploration of the inquiry-based investigations made by non-experts in collaboration with science experts. However, the differences include that the Fossil Finders is an offline project which applies to school-children and it is guided directly by teachers and scientists.

4.3 Research Questions

This study focuses upon the engagement of amateur geologists with the scientific investigation of rocks and the research question is shaped accordingly to this theme:

“How can citizens engage in inquiry-based learning through peer collaboration and mentoring by experts within informal settings?”

Focusing on the main components of the research question, the following aspects were investigated, addressing the following issues:

rq1 – motivation: The first step for rock hunters to engage in the investigations was to join the community. Thus, the motivations for joining a Citizen Inquiry of rock investigations were researched.

rq2 – IBL: This aspect explores how participants engaged with the inquiry process. To this end, it was studied whether the investigations had all of their phases complete, rock hunters from all level of expertise published investigations, more expert participants used more geology-specialised words in their investigations, and beginner rock hunters found it more difficult to form a research question

rq3 – collaboration: The ways that participants preferred interact is an important aspect of a community that promotes collaboration. Hence, it was examined whether participants preferred forum or chat and with whom they opted to communicate (science experts or non-experts).

rq4 – mentoring: Mentoring from science experts to non-experts is a main challenge in Citizen Inquiry. Therefore, the kind of help non-experts ask for and how they make use of it was researched. Firstly, the influence of expertise level on the participants’ role in the community was investigated. Then, it was explored whether non-experts need and seek more help than more advanced participants to plan their method, and look for this help within the community.

rq5 – inquiry-led environment: The nQuire platform (Section 4.4) was the web-based inquiry environment that hosted Inquiring Rock Hunters. An issue to investigate was the effectiveness of nQuire to support learning and engagement. To this end, the usability of the platform and the satisfaction of the participants with the environment were researched.

rq6 – experience: Beyond the examination of the investigations, a self-report by participants on their experience provided insight into what kind of learning happened through their participation in the project.

The data collection and analysis methods used to address these issues were described in Chapter 3 (Section 3.5).

4.4 nQuire Platform

nQuire was developed to support Inquiry-based activities for secondary education science learning within the Personal Inquiry project (Sharples et al., 2014) and further developed within the Open Science Laboratory³³. Figure 11 shows a snapshot of the nQuire homepage created for Inquiring Rock Hunters.

The nQuire platform was first used to support Citizen Inquiry with the development of ‘Moon Rock Explorer’, a prototype system and activity on the Geology of Moon Rocks (Villasclaras-Fernandez et al., 2013). The Moon Rock Explorer offered the participants the opportunity to use a Virtual Microscope and get involved in investigating specimens of Moon rock (Figure 12). The evaluation of the project looked at motivation and interaction between the participants, as well as at the suitability of nQuire to support citizen inquiries.

³³ <http://www.open.ac.uk/researchprojects/open-science/>

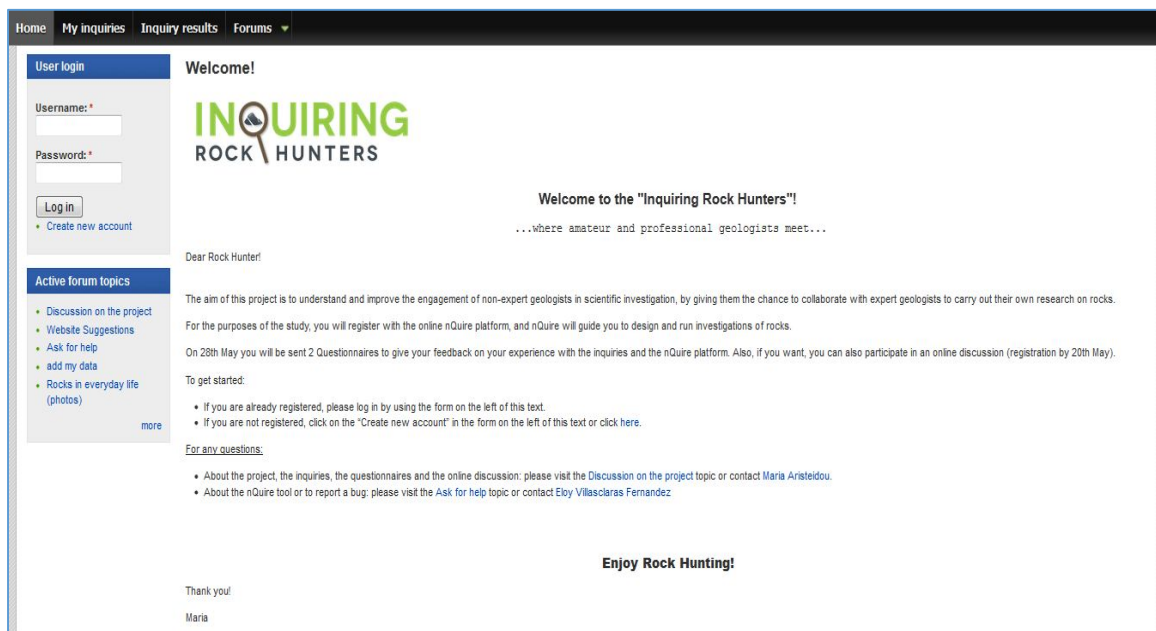


Figure 11: Inquiring Rock Hunters – home page

Moon Rock Explorer reduced the number of inquiry phases used in the Personal Inquiry project from eight to six, merging the *answer to the question*, the *discussion* and the *reflection* into one phase. The six phases were: Introduction, Decide my question, Plan my method, Collect my data, Analyse my data, Decide my conclusions. The participants had access to high resolution microscope images of the moon rock samples, asked questions related to the samples, planned the measurement method, collected data via the Virtual Microscope, visualised and analysed the data through graphs and published their findings through the forum. For this purpose, a new version of nQuire was developed by Villasclaras-Fernandez that allowed for the absence of a teacher, by providing more informational text to the inquiry phases and allowing the participants to re-visit and revise their investigations at any point and also supported the online interaction between the participants through a forum.

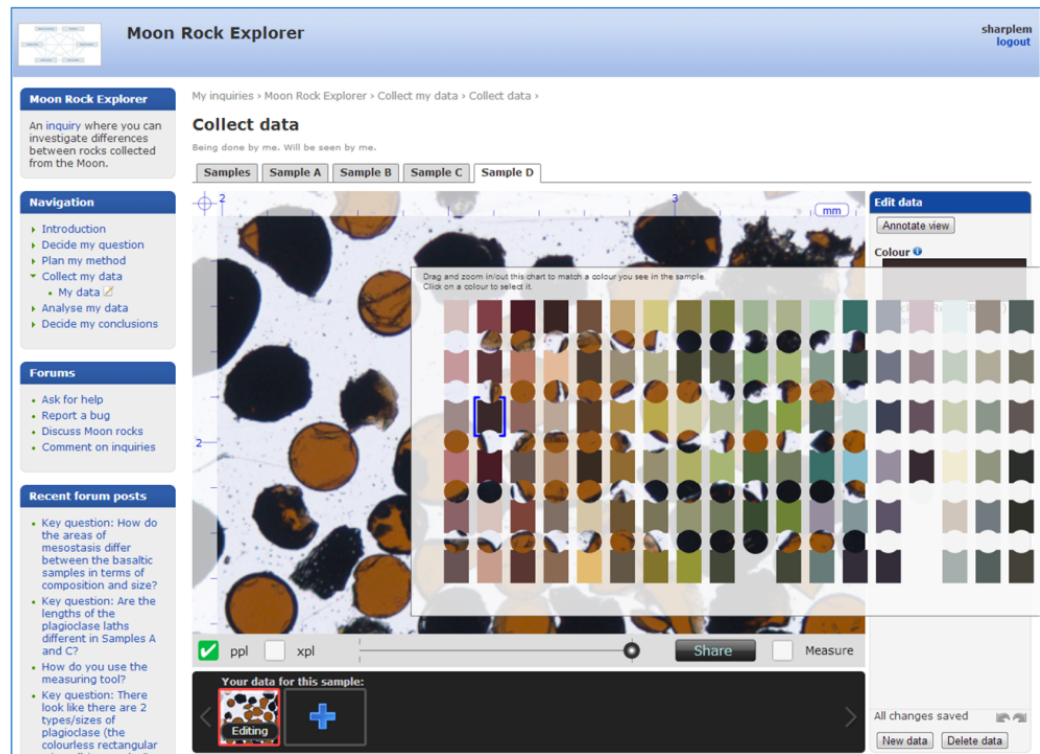


Figure 12: Screen display from Moon Rock Explorer (Villasclaras-Fernandez et al., 2013)

nQuire was then adapted and customised to support the development of Inquiring Rock Hunters.

The distinctive aspects and the nQuire features that supported this project are:

- *IBL*: authoring tool, inquiry diagram
- *Communication*: forum, chat, inquiry results menu
- *Mentoring*: geology knowledge and techniques, sources, experts
- *Informal settings*: integrated tools, tutorials

Some important differences between the nQuire platform version supporting the 'Moon Rock Explorer' and the version supporting 'Inquiring Rock Hunters' are shown in Table 12.

Table 12: Differences between Moon Rock Explorer and Inquiring Rock Hunters

Moon Rock Explorer	Inquiring Rock Hunters
Investigations automatically published on a forum	Investigations published manually by the participants (optional) on the Inquiry Results menu
The design included PhD students, experts in the topic	The design had intention to include in the project participants of different levels of expertise
The platform included the Virtual Microscope	The platform did not include Virtual Microscope, but included Google Maps
There was informational text to the inquiry phases	Apart from the informational text on each activity, there was also an image/text tutorial along with a video given to the participants
Communication was through the forum	Apart from the forum threads, chat and communication through the published investigations were added

The above changes were given to Villasclaras-Fernandez to develop before the pilot study (Section 4.6). In the following section there is a more detailed description of the nQuire tools and how these are used to support aspects of Citizen Inquiry, such as IBL, communication and mentoring.

4.4.1 Home page

Once the participants enter and register with the platform, they can navigate through the top menu to the:

- My inquiries: The list with the available inquiries (Geology inquiry)
- Inquiry results: The journal with the inquiry results
- Forum: Forum threads for discussion

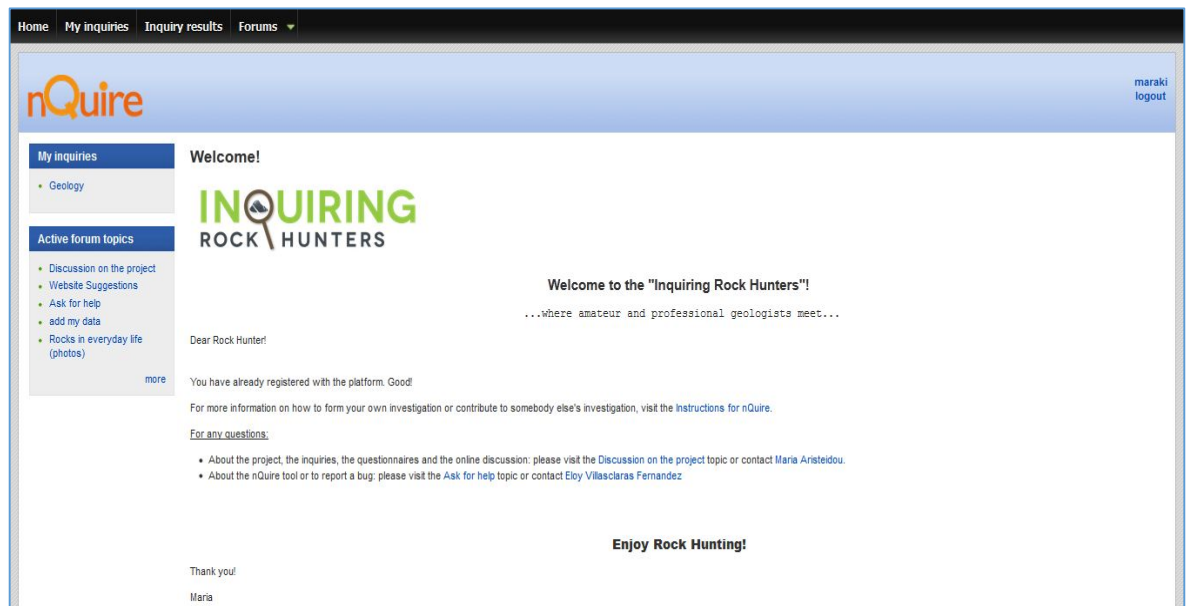


Figure 13: Home page – menu

Also, the menu on the left gives access directly to the Geology inquiry and the recently active forum topics (Figure 13). The home page provides some information giving help on how to use the nQuire platform and the inquiry.

4.4.2 Inquiry creator

An inquiry authoring tool (Figure 14) was developed within the nQuire toolkit (Villasclaras-Fernandez et al., 2013) to allow the instructor to design the sequence of the Citizen Inquiry phases and activities.

INQUIRING ROCK HUNTERS
Geology
 Do you like rocks and minerals? Would you like to ask questions about rocks and discover more about them? "Inquiring Rock Hunters" is to help people engage in scientific investigation, by giving them opportunities to collaborate with scientists and run their own research about rocks!

edit

Edit phases and activities Edit temporal organization Edit collaboration organization Edit roles

▼ Phase 1: Decide my theme edit delete
 • My notes about the theme edit delete

▼ Phase 2: Form my question edit delete
 • My hypothesis edit delete
 • My key questions edit delete

▼ Phase 3: Plan my method edit delete
 • Notes about my method edit delete
 • Decide my measures and tools edit delete

Phase Name: *
 Form my question
 Write here the name for the phase.

Phase Description:
 In this phase, you can form a question in relation to your inquiry.
 The inquiry can be formed as a hypothesis or as a question.

Example:
 1. How can I recognize what type of rock this is?
 2. Is there any calcite in my location?

A brief description of the phase objectives. This will help the inquiry participants understand their tasks.

Save Cancel

Figure 14: Inquiry authoring tool

The authoring tool in addition to producing phases, activities and their instructions, is used to determine the collaboration level for each activity (individual, in group, all together). In this study, the activities were performed individually as the time limit of the first design study did not allow space for collaborative investigations. For the same reason, all the activities were carried out in one chronological stage, with all the activities being active and accessible throughout the whole period of time. Finally, the roles of the inquiry activities were divided into two categories: the owner and the participants in the inquiry. At this point the owner of the inquiry decides the level of access of the participants in each inquiry phase: no access, view, comment, edit.

4.4.3 Inquiry diagram and tools

In classroom-based learning, the teacher is needed to provide guidance and ensure the quality of questions and methods planned by the learners (Sharples & Anastopoulou, 2012). In online IBL the role of the teacher is transferred to computer systems that provide this guidance and support the learners through a structured process (Linn & Slotta, 2013). The nQuire platform supports the learners in managing their investigation through a Citizen Inquiry support system (Villasclaras-Fernandez et al., 2013) to which amateur geologists have access through the inquiry diagram.

The inquiry diagram (or inquiry learning framework) is one of the important features of nQuire and is the graphical representation which conveys the cyclical sequence of the inquiry phases

(Figure 15). Within the activities provided in each phase of the diagram, there are inquiry tools available for the collection, analysis, visualisation of data and dissemination of findings.

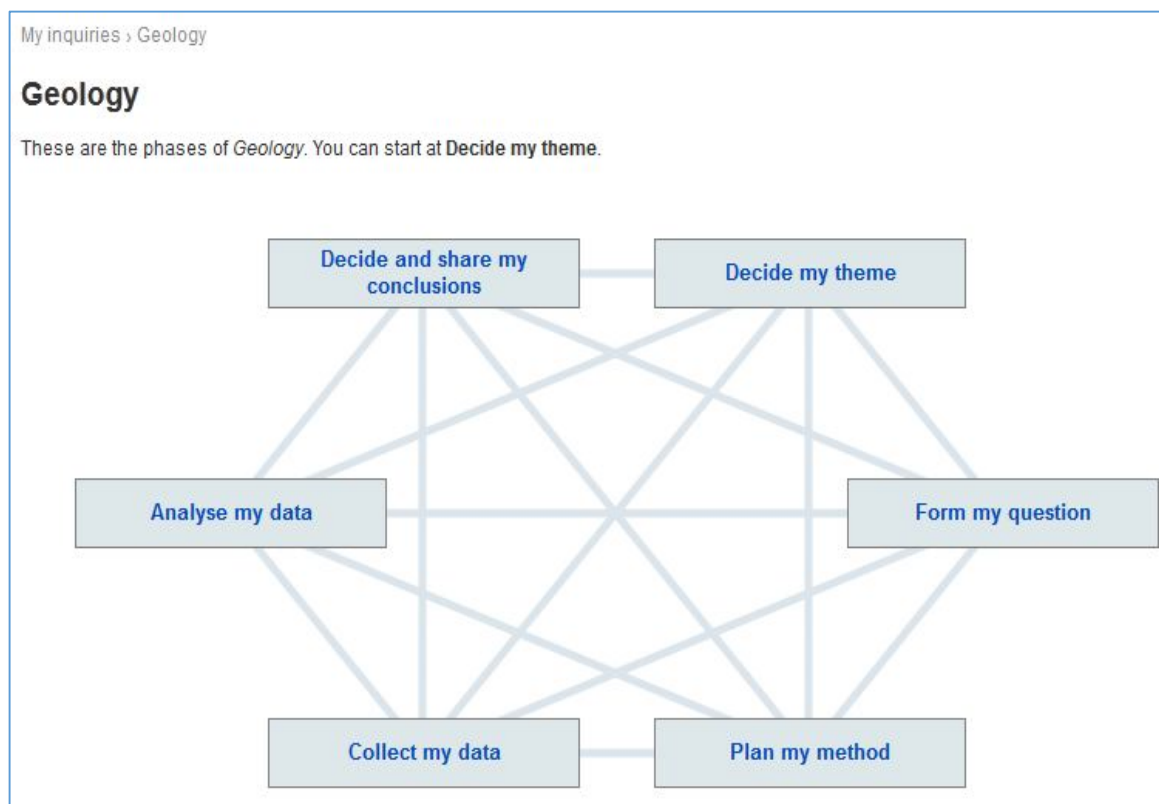


Figure 15: Inquiry diagram – cyclical sequence of phases

The phases produced through the Authoring tool for ‘Inquiring Rock Hunters’ are:

- *Decide my theme*: Entering at the ‘Decide my theme’ phase, the users have to decide on and describe the background of their investigations as they are the owners of their investigation. Some theme examples are: fossils, earthquakes, rocks of different colours, rock hardness, minerals, etc.
- *Form my questions*: The users propose a hypothesis and then a number of research questions (at least one), derived from the hypothesis, in order to explore its validity. The questions depend on the users’ level of geology expertise and may be related for example to the rocks identification or comparison.
- *Plan my method*: This phase is to plan a method of investigation and then choose the tools and measures the users are going to use for their investigation. nQuire provides

some ready-to-use tools (i.e. image upload, Google maps position) and measures (i.e. number, date, text), and the users can choose some of these (both tools and measures) to use or add new measures. The tools and measure that will be chosen in this phase, will appear in the proforma (Figure 16) provided in the next phase.

Length of rocks (cm): *

Colour of rock: *

Number:

Image upload:

Browse...

Google Maps position:

Map Satellite

North Sea

Denm

United Kingdom

Ireland

Netherlands

Belgium

Gerr

Google

Map data ©2013 Basarsoft, Google - Terms of Use

Mark centre Center on marker Forget marker

Save

Figure 16: Data collection – proforma

- *Collect my data:* After deciding the methods, tools and measures they want to use for their investigation, users can find their choices available in this phase through the proforma. The users can also include and share other findings retrieved from tools and other sources outside nQuire in the provided notepad.
- *Analyse my data:* Having collected their data, users may want to analyse them by creating graphs through the spreadsheet tool for the selected measures.
- *Decide and share my conclusions:* Lastly, users can propose answers to their questions based on their personal interpretations of the analysis and conclude whether their initial hypothesis was valid or not.

The participants can access the diagram at any point in their investigation. All the phases are interconnected, thus, users can lead their own investigations, guided by the scientific process given in the diagram. Also, they can visit and re-visit all the phases at any time, refining their investigations (Villasclaras-Fernandez et al., 2013). For the navigation within the activities, there is also a menu available on the left (Figure 17) giving the proposed order of the phases and activities in detail. This inquiry diagram is the scaffolding tool that allows the participants to design and manage their investigations in a self-directed way. Finally, the participants are limited by the nQuire platform to conduct only one scientific investigation.

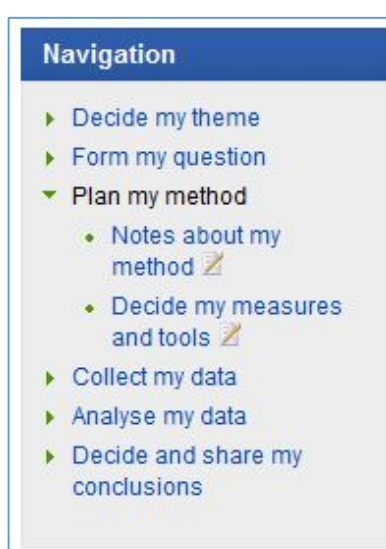


Figure 17: Navigation menu

4.4.4 Publish Investigation

The nQuire platform provides the users with two ways to share their investigation and its results with the other people involved in conducting the inquiry. Sharing of results is considered a significant part of Citizen Inquiry as it provides learners the opportunity to give and receive some feedback on their scientific procedure and their findings, as well as to interact with the other participants with a higher level of geology expertise, such as professional or expert geologists. The investigations can be shown a) step by step within the diagram, if you choose to see what other participants are doing or b) through the inquiry results menu (Figure 18) which gives a summary of the data for each phase of a participant's investigation.

Inquiry results

Investigations for *Geology*:

- View [investigation results](#) of user aristeidoum
- View [investigation results](#) of user evilfer
- View [investigation results](#) of user maraki
- View [investigation results](#) of user sharplem
- View [investigation results](#) of user carolineheathfieldbarker
- View [investigation results](#) of user Nuria
- View [investigation results](#) of user marinabinoc
- View [investigation results](#) of user Rockhound
- View [investigation results](#) of user alecthomson
- View [investigation results](#) of user kosmas
- View [investigation results](#) of user Ros24
- View [investigation results](#) of user geohunter
- View [investigation results](#) of user nordie69
- View [investigation results](#) of user Yoseph
- View [investigation results](#) of user Daisy
- View [investigation results](#) of user Laila Burton

Figure 18: Inquiry results list

The publishing of the investigation depends upon each participant's decision whether or not they want their work to be public and accessible by other people. As shown in Figure 19, the 'share content' menu provides options for making users' investigation visible within the diagram (inquiry participants, just me) for every activity or publishing the whole investigation in the Inquiry results menu – Publish investigation tick-box.

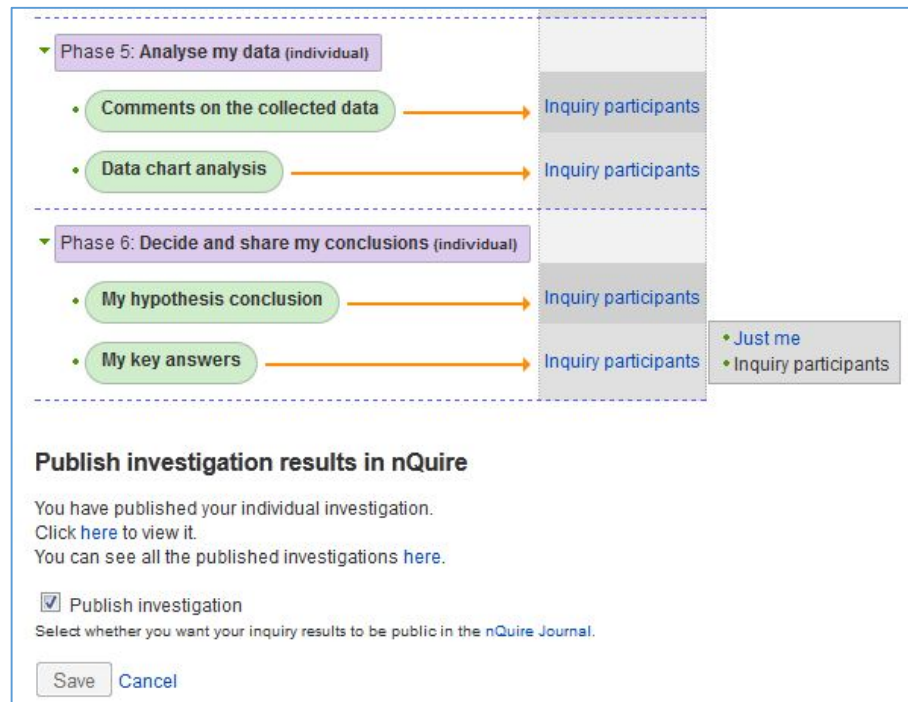


Figure 19: Share content menu

4.4.5 Communication tools: Forum and Chat

The nQuire platform integrates online community support through forums and chat. These two communication tools are used as a community meeting point that supplies the participants with support for their investigations. The forums (Figure 20) consist of three categories:

- Geology Forum: FAQ topic, sources to support the investigations and questions related to geology.
- Inquiring Rock Hunters Forum: questions and updates on the project.
- nQuire Forum: help for the nQuire platform and the tools, suggestions for improvements.

Forums				
<input type="button" value="Mark All Read"/>				
	Forum	Topics	Posts	Last post
	Geology	4	21	Rocks in ... by salmk1 21/05/2013 - 09:13
	Inquiring Rock Hunters	1	3	Discussion ... by aristeidoum 29/05/2013 - 10:09
	nQuire Discuss here any suggestions you have about nQuire, or report problems you come across. Updates to nQuire will be announced here.	7	33	Website ... by aristeidoum 27/05/2013 - 14:52

Figure 20: nQuire forums

In general, forums are widely used in citizen science (Bonney et al., 2009) and in this project are the means by which help is provided to the non-expert geologists to assist them either to improve their investigations or to gain more knowledge through other participants' discussions. Thus, learners build shared understanding while engaging and collaborating and sharing common resources (links, text, video, pictures) in forum discussions (McCann, 2009). Also, the forum provides the flexibility for the users to reply when they have free time. They have more time to process the information, comprehend the wording and structure the response (Robert & Denis, 2005).

Alongside the asynchronous communication that the forum provides, there is also the option of synchronous communication between the participants as sometimes this is preferred because it overcomes the communication delays (Revere & Kovach, 2011). Chat (Figure 21) gives the participants direct connection with the instructor, the geology experts and the other participants and promotes real-time collaboration and discussion. This kind of spontaneous interaction aims to build positive relationships and the foundations for communities of practice (Angelino, Williams, & Natvig, 2007) like Inquiring Rock Hunters.

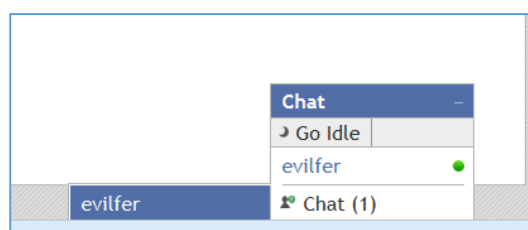


Figure 21: nQuire chat

4.5 Tutorial and Instructions

Prior to the project's launch some guidance for the participants was prepared, such as:

- 'Instructions for nQuire platform': online tutorial (plus pdf format) on the Open Inquiry Learning blog (Figure 22).

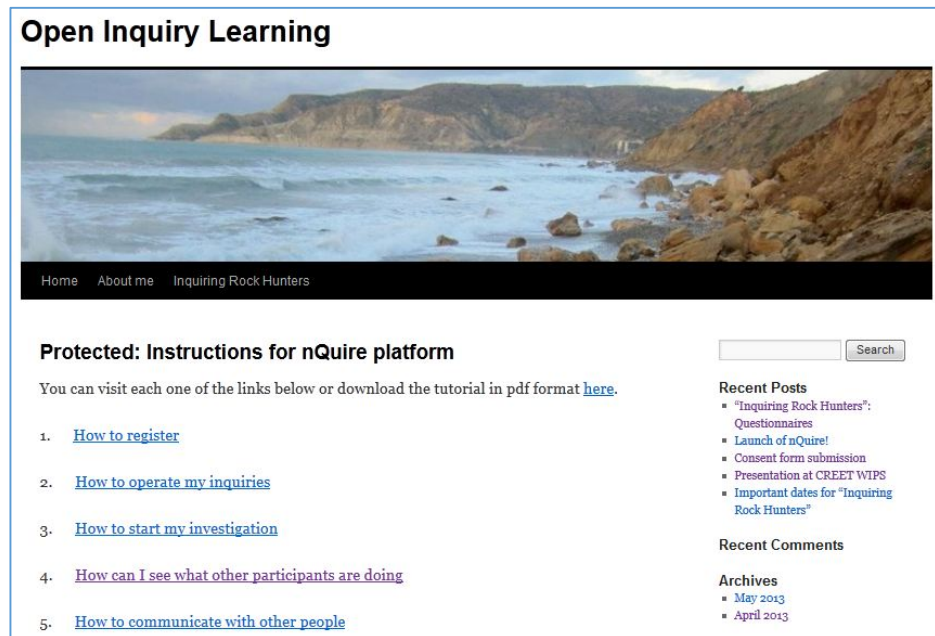


Figure 22: Open inquiry learning blog

- 'How to publish my investigation': video available at <http://www.youtube.com/watch?v=78eUanIJkl>
- 'Useful websites': available on the Geology Forum <http://www.nquire.org.uk/node/1134>
- 'Questions to experts and FAQs': available on the Geology Forum <http://www.nquire.org.uk/node/1159>

In addition to the above, some other forum topics were also added to facilitate the participants' engagement with it (e.g. General Discussion).

Subsequent communication emails to the participants of the project included:

- A reminder on how to publish their investigations.
- An invitation to fill in the questionnaires and attend the online focus group /interviews.
- A reminder for the questionnaires.

Finally, an exemplar investigation was created by the researcher in order to help the participants get familiarised with the inquiry phases and the material that goes to each one. The investigation was on 'rocks and colours' exploring the sizes and colours of rocks in an area. The investigation

was completed with analysis of the collected data and getting help from a geology expert who left her comments under the researcher's investigation.

4.6 Pilot study and results

The Inquiring Rock Hunters project went through a test-drive phase before its final launch to the participants. In this pilot stage people from the researcher's familiar environment, such as friends and colleagues, volunteered to participate. The participants, aged 24-40, had diverse backgrounds (computer science, educational technology, physics). The aim of the pilot was to receive some feedback on:

- The nQuire tools
- The instructions for each phase/activity
- The text/images tutorial
- The forums
- The questionnaires
- Anything the participants considered needed improvement

The time allocated for the pilot study was not to exceed eight days and so the five participants received a compact email including the tutorial, the invitation to the nQuire platform, the questionnaires and the online focus group. It should be noted that a) one expert was added as 6th participant in case some support was needed in the investigations; b) the participants were not in principle interested in Geology but in the nQuire platform's operation. An overview of the data collection is shown in the table below (Table 13):

Table 13: Pilot study – data collection

Type of Data Collection	Number of items
Questionnaire	4
System Usability Scale	5
Investigation Questionnaire	2 (published investigations)
Online focus group	0

For the evaluation of the pilot study, the data collection and analysis methods for Design Study 1 were employed and tested. The results of the evaluation showed:

IBL: only two of the five participants published their investigations and that was mainly because they were not familiar with Geology and thus *“didn’t feel self-confident”* to publish their work. Also, they were mainly *“looking at the platform itself”* and did not put much effort to create an investigation. However, one of the participants noted *“I have learnt how to organise an inquiry”*.

Collaboration: The preferences on ways of communication were: forum topics (57%), Question to expert (29%) while Online Chat had no votes and one of the participants indicated *“mails or tweets”* as the most preferable way. Some reasons the participants gave for their preferences were: *“I like having contact that is not linked to specific times”*, *“I prefer the forum communication because more people can see the answers and they can participate in the discussions”* and *“I’d like to know an expert was available for technical questions, but gather the purpose of an inquiry-based activity is to encourage non-experts to plan and conduct investigations amongst themselves”*.

Mentoring: None of the participants noted in the questionnaire that they had received help. An explanation for this was that they *“did not look for any help at this point”*. Another reason for not

receiving any help is probably because they did not create an investigation. However, there was an interaction on the forum where the expert gave information about fossils' maps to a non-expert participant.

nQuire tools: Regarding the tools participants used in their investigations, the “rock identification key” (external tool) was the most popular, used by two participants. Other tools they used were notebook, microscope, camera and maps. For the latter two, there was a suggestion whether *“the tool would be able to have location based information practically linked to uploaded (metadata enabled) content, like pictures taken with mobile phone camera”*. Some other suggestions for tools were: *“spectrophotometer”, “smartphone layout (simpler design)”, “RSS option”, “A way of quickly checking what data others working on similar inquiries had found”*. There was also a bug report: *“menu disappeared”*.

The results from SUS showed that the usability of the nQuire platform reached an average of 66.5%. SUS was really useful as it covered several aspects of the tools such as the need for training or support for its use and the usability and complexity of the system. This percentage will be useful when comparing it with the results of SUS scale in the pilot-study after improving some aspects of the tool based on the pilot study's feedback.

Online focus group: The online focus group was cancelled as the participants were not willing or did not have time to join.

Feedback on questionnaires: The participants also gave some feedback on the structure and design of the Questionnaires such as:

- Add an N/A option in all the questions
- Make some questions optional
- Change the order to some questions
- Change some questions to follow-up questions

Finally, some other suggestions in relation to the nQuire platform were: *“link to the instructions in every activity”, “video with a completed inquiry” and “add pictures and movies when entering the platform”*.

Changes on nQuire and questionnaires

After receiving feedback from the pilot participants and detecting some bugs in the platform, some changes took place. The time available between the pilot study and the Design Study 1 was limited and thus only some important adjustments occurred:

- The ‘join the inquiry’ procedure became simpler. The users could become members of the inquiry once they registered with the platform.
- A ‘Geology’ menu was added on the left of the page as well as the logo on the top. People could access the geology inquiry only with one click.
- The ‘Inquiry diagram’ was changed from vertical to hexagon.
- An ‘Active forum topics’ menu was added on the left of the page, showing the recently active topics on forum.
- The ‘Forums’ layout was changed to maintain the chronological order in the posts and take less space for every post. Also, an “uploading picture” feature was added.
- The ‘Phase’ view was simplified: user’s content was only shown inside the activity view and not in the phase view.
- A ‘Video’ on how to publish your investigation was created.
- The image/text tutorial was updated to follow up the above changes.

After changing the above, the Design Study 1 ran with the new participants, the rock hunters. The following section demonstrates an overview of the project’s settings and the collected data.

4.7 Design Study 1 – Data Collection

The final number of participants in Inquiring Rock Hunters was 24. The participants registered with the nQuire platform and got involved with their investigations by using the inquiry diagram. The study lasted for three weeks and twelve investigations were published. The two questionnaires were filled in during the third week of the project with some time extension of one week. Questionnaire A collected data for all the four aspects of the project (Inquiry, Collaboration, Mentoring and Software); System Usability Scale (SUS) provided information about the effectiveness, usability, usefulness and desirability of the nQuire platform. After the official day the study ended, an online focus group took place at Hangouts on Air. However, only two people were available to attend the discussion so extra invitations for private online or face-to-face interviews were sent. Seven participants gave positive responses and the interviews were scheduled based on participants' availability and means of communication preference. Table 14 shows the data collection from the questionnaires, the interviews and the online focus group.

Table 14: Design Study 1 – data collection

Type of Data Collection	Number of items
Questionnaire A	20
System Usability Scale (SUS)	22
Investigations	12 (published investigations)
Interviews	4 Facebook
	2 face-to-face
	1 Google Hangouts
Online focus group	1 of 2 people (Hangouts on Air)

The following diagram (Figure 23) presents the interactions between the participants during the period of the Inquiring Rock Hunters project. Each node corresponds to a participant. The number of the participants in the circle is 28 as some of the contributions from pilot study participants are also included in the interactions – the Design Study 1 participants commented on their contributions.

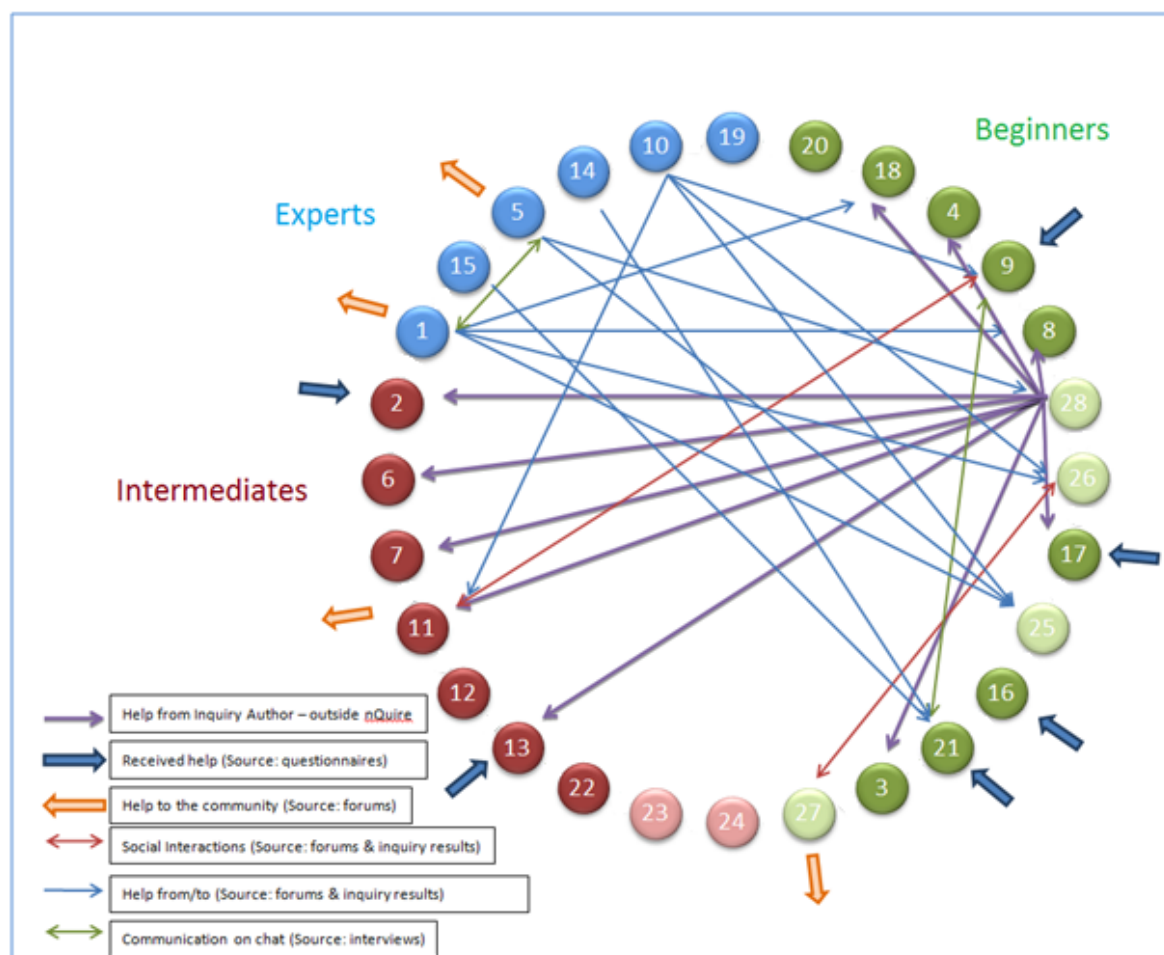


Figure 23: Interaction circle

Different colours on the numbers symbolise the different levels of expertise of the participants (based on the questionnaire responses). The blue colour indicates the expert, the brown colour the intermediate and the green colour the beginner level of expertise. The participants 23 and 24 did not fill in the questionnaire and their level of expertise is unknown. However, according to the information they gave on their application and the justifications the other participants gave for being users of intermediate expertise, they can be considered as intermediate level of expertise too. Two other participants who did not fill in the questionnaire are represented by the numbers

19 and 20. The level of expertise of these participants is known, as number 20 who is a beginner mentioned their level of expertise during the interview and number 19 was initially invited to the project as an expert. The light green numbers represent the moderators of the platform, with number 28 being the PhD researcher.

The blue arrows inside the circle which connect numbers represent the interactions recorded by means of observation of the platform (forum and inquiry results). The number at the start of the arrow is the person who provided help and the number which the arrow is pointing at is the person that received help. The blue arrows outside the circle pointing towards the numbers show the participants who received help, according to their responses in the questionnaire. The two-way green arrows inside the diagram show the communication between participants on the chat, according to the interview record; the purple arrows show the help provided outside the nQuire platform by the researcher (email, Facebook). Also, the orange arrows starting from the numbers and pointing to the outer space show the help provided to other rock hunters by these participants, as observed by their activity in the nQuire platform. Finally, the two-way brown arrows indicate the social interactions between the participants during their collaboration on the nQuire platform. There were no other topic-related interactions that are not help seeking/giving between the rock hunters.

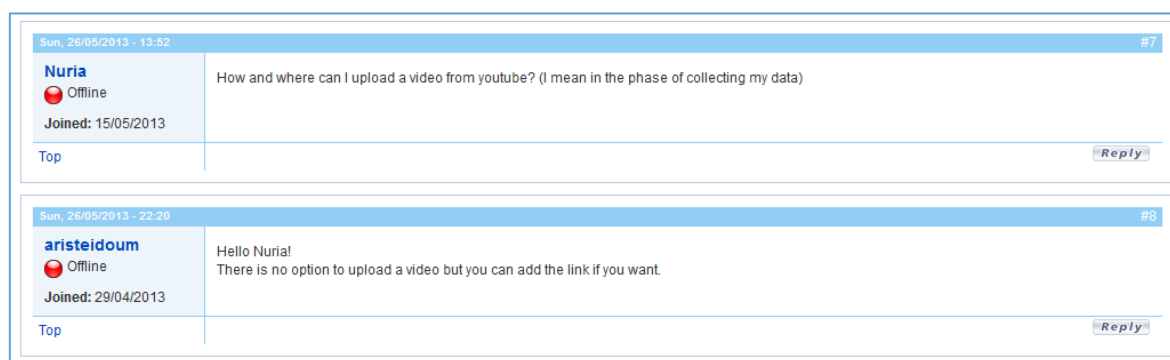


Figure 24: nQuire forum – asking for help

Some interactions between the participants took place on the forum and on the Inquiry Results. A sum of 60 messages was posted in twelve forum topics. The messages were mainly focused on

the nQuire use (e.g. Figure 24) and the identification of rocks (e.g. Figure 25). In addition to that, 14 participants contacted the researcher via email, Facebook or chat and asked for help.

Mon, 20/05/2013 - 00:23


#1

marinabinoc

Offline

Joined: 15/05/2013

Hello! My name is Marina and I am a primary school teacher!
When I was young my grandfather used to tell me stories about his trips around Greece. I remember him having a "magic box" where he kept hidden marvellous and mysterious things! Well, what I strongly remember is that he kept showing me a "precious" metal-like stone. I was really amazed by that little shiny rock because he insisted that it was gold!
I know that it is not gold, but what is it???



Top

Reply

Mon, 20/05/2013 - 09:26

#2

geologyclare

Offline

Joined: 17/05/2013

Hi Marina,
This looks very much like "Fools Gold", or iron pyrite - FeS_2 . It forms crystals, unlike "real" gold, which does not. It is also harder than pure gold, and the colour is browner, more brassy. There is also a mineral called "chalcopyrite" which is the copper version. The colour of this one is more coppery, and sometimes you can find both iron pyrite and chalcopyrite in the same rock.

Top

Reply

Mon, 20/05/2013 - 09:58

#3

TomHopkinson

Offline

Joined: 03/05/2013

Hi Marina,
I remember my parents had lots of amazing rocks and minerals in a small collection too, which might have been what got me into geology as a child.
I think what you have there is a sample of pyrite, or iron sulphide. This is also known as "fool's gold" - as people in the past have found samples of it and thought they'd struck it rich. However, you've correctly identified it as not being gold! It's a semi-rare mineral that forms these very pretty opaque golden-coloured crystals that often appear cubic. It's certainly a lovely sample of it - you're very lucky for having it in your collection!

Hope this helps,
Tom

Top

Reply

Figure 25: Geology forum – questions to experts and FAQs

Three messages were published under the investigations (e.g. Figure 26). The expert geologists had also commented on investigations produced by pilot participants increasing the number of the messages into seven.

My hypothesis conclusion

Conclusion: That the dark rocks and the light rocks in the stone walls on the A53 south of Buxton are not the same material. The light rocks are limestone but the darker rocks are sandstones.

After I examined my rocks I looked at a geology map of Buxton and found out the following:
 The rocks to the east of the A53, and under it, are the Chee Tor Rock limestones.
 The rocks to the west of the A53 are the Kinderscout and Longnor Sandstones within the Shale Grit.
 This is a faulted unconformity. This fault runs along one side of Stanley Moor Reservoir, which is why it always leaked!

My key answers

- What do the different coloured rocks look like, composition and strength
 - The lighter rocks are harder, contain fossils and do not show any grain size The darker rocks are softer, contain grains up to 1mm in size which are sub-angular,

Add new comment

Comments

Submitted by [tomargles](#) on Mon, 20/05/2013 - 16:06.

A quick comment on the acid test: vinegar will work, though you might have to scratch the sample to powder it for a reaction to occur. The scratch test in any case should distinguish between calcium carbonate (calcite in limestone) and silica (quartz in sandstone).

Good luck!
Tom

[reply](#)

Figure 26: Inquiry results – comment on published investigation

Further description of the analysis outcomes follows in the next section.

4.8 Design Study 1 – Findings

This study focuses on the improvement and support of Citizen Inquiry and the findings of this study relate to the main research question: *“How can citizens engage in **inquiry-based learning** through peer **collaboration** and **mentoring** by experts within **informal settings**?”*

The ‘Inquiring Rock Hunters’ project had twenty four participants registered with the nQuire platform: six expert, nine intermediate and nine beginner rock hunters. The experts were PhD students or researchers from the OU Geology Department, the intermediates were mainly people attending Geology modules or holding a BSc in Geosciences and the beginners were mostly either hobbyists who are fond of travelling and looking at nature or people interested in educational technology or citizen science.

The following sections summarise the findings regarding the six basic themes that emerge from the research questions (Section 4.3).

4.8.1 Motivations

A survey question was administrated to find out what stimulated the participants to take part. The results revealed the reasons why the rock hunters participated as volunteers in this study (Figure 27). No reward was offered for their contributions to the project.

The rock hunters were mostly driven by personal incentives (blue – 60%) to take part to the project (e.g. geology and geological fieldwork, learning about science, PhD projects and other new things, having fun). Curiosity (orange – 23%) could also be considered as personal incentive, but in the pie chart it is shown separately to give emphasis to the specific type of curiosity the participants had (e.g. pedagogical curiosity, meeting people from other countries, checking out technology). Thus, the personal motivations, excluding curiosity, amount to 60% of the total number of motivations.

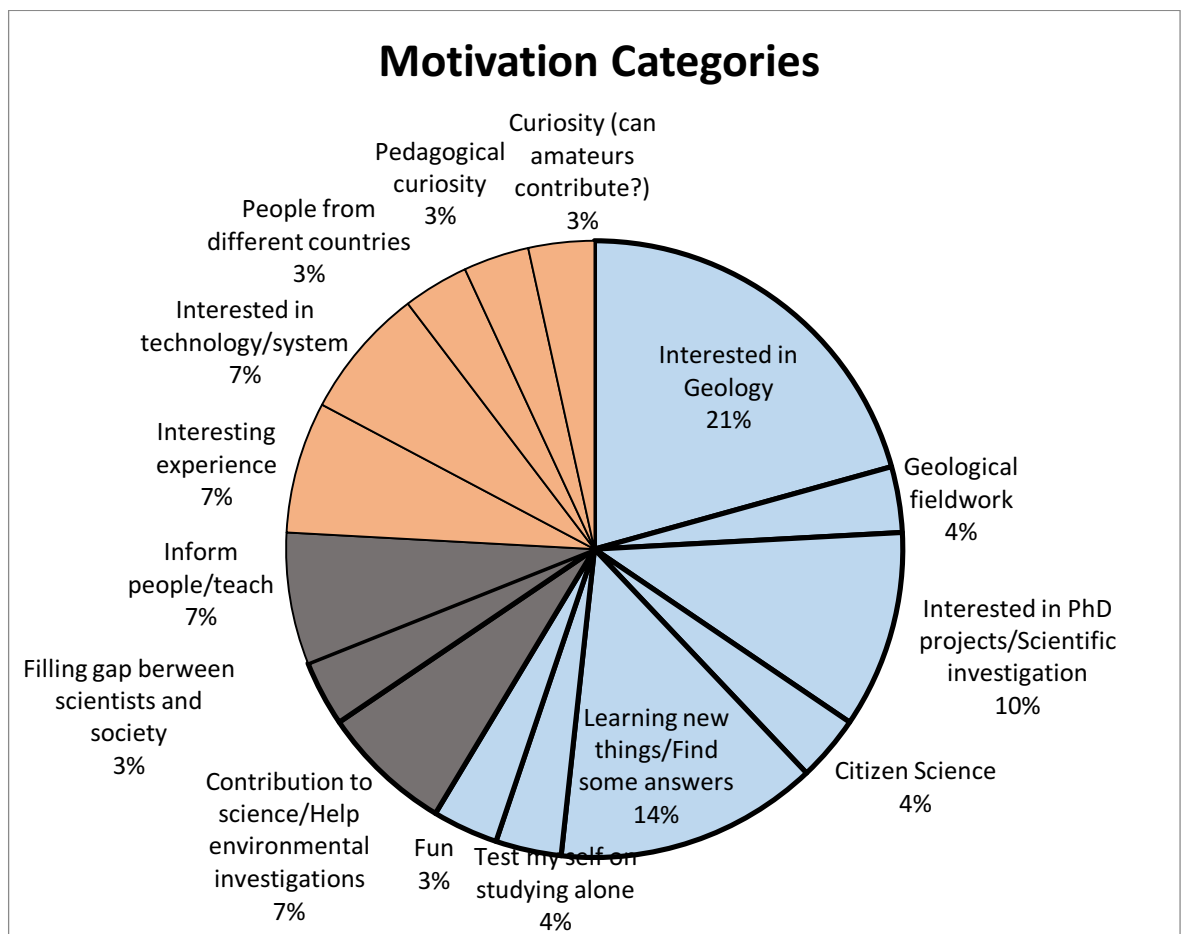


Figure 27: Motivations for joining Inquiring Rock Hunters

Beyond the personally-focused reasons, some participants had the intention to offer their knowledge or to add their input to a study which they considered to be a contribution to the society and science (grey). These motivations amount to 17% of the total and are comprised of informing people, contributing to science and filling the gap between science and society.

4.8.2 Inquiry-based Learning

Of the twenty four participants, half (12) published an investigation on rocks. The published investigations were created by beginner (7) and intermediate (5) rock hunters, while none of the experts published an investigation (four out of six experts did not create an investigation).

The themes of the investigations focused on were as follows: a) general geology issues such as mountains and earthquakes, b) specific rock-related topics such as rock shape, colour, or hardness and c) more specialised topics, such as fossils and minerals. Almost all of the investigations were location-based.

In the list of the published investigations, there are seven completed (i.e. those including conclusions) and five incomplete. However, only five of them have all the inquiry phases completed as the 'analyse my data' phase was skipped most of the time. Of the incomplete investigations, two of the investigation owners had received feedback and found their answers through the forum, but they did not add their analysis and conclusions to their investigations. An explanation given by an interviewee for not finishing their investigation was *"I didn't finish my investigation because of lack of time"* (RH. 20) which appears to be the main reason given for many other incomplete tasks and activities (e.g. not participating in forums, not finding more data, etc.). In addition to the above, an interesting explanation came from one of the interviewees who indicated being *"afraid of the data analysis phase"* because *"it might lead me to wrong conclusions"* or *"will use the knowledge received by the experts without understanding the conclusion"* (RH. 21). Despite this, the particular participant carried on their investigation until the end.

Regarding the ‘plan my method’ phase, intermediate rock hunters appear to use more specialised methods (e.g. “test with dilute HCl”, “collate graphic logs of the area”) and provide better annotation in their measures (e.g. date, fossil specimen, grain shape), instead of ‘text’ or ‘number’.

The survey responses mostly indicated satisfaction on the part of the rock hunters for the inquiry framework because they liked the way they were driven by the flow to “*collect all the data and reach to the conclusion*” (RH. 16) as well as the way the inquiry framework helped them to “*organize the material*” (RH. 9), which they reported to be difficult to do alone because of lack of time.

In Table 15, the white-coloured users represent the beginner rock hunters and the light blue-coloured users the intermediate ones. The results took into account the background of the participants and/or the type/length of the investigation. The conclusions from the vocabulary analysis indicate that the use of scientific geology-based vocabulary is subject to the data collection sources, the length of the text, the type of the investigation (e.g. literature, field-work, rock identification), the level of geology expertise, the background of the researcher and the completion status of the investigation.

Table 15: Frequency of Geology terms

Number	Rock Hunter	Count of Geology words	Single words
1	RH. 9	48	18
2	RH. 8	53	17
3	RH. 11	21	10
4	RH. 13	18	10
5	RH. 6	14	9
6	RH. 4	16	6
7	RH. 7	4	3
8	RH. 16	7	3
9	RH. 18	16	3
10	RH. 21	5	3
11	RH. 22	5	3
12	RH. 17	2	1

In general, the frequency of geology-specialised words used did not differ very much between the beginner and intermediate rock hunters because some of the beginners referred to and used text from geology related sources, which increased the geology terms in their investigations.

The following table (Table 16) was extracted from nVivo and demonstrates the words that are most used (>10 times) in all the investigations during the project:

Table 16: Investigations - Frequently used words

Word	Count	Similar Words
rocks	81	rock, rocks
mountain	35	mountain, mountains
find	28	find, finding, findings
found	24	found
different	21	difference, differences, different
area	20	area, areas
plates	19	plate, plates
geology	16	geologic, geological, geology
colours	15	colour, coloured, colours
earth	15	earth
limestone	15	limestone, limestones
material	15	material, materials
fault	14	fault, faulted, faulting, faults
workings	13	work, worked, working, workings
earthquakes	12	earthquake, earthquakes
formed	12	form, formed, forms
fossils	12	fossil, fossils
look	12	look, looked, looking
beach	11	beach
interesting	11	interested, interesting, interests
maps	11	map, mapped, mapping, maps
shaking	11	shake, shaking
tectonic	11	tectonic
way	11	way, ways

All the words are related either to geology (“rock”, “mountain”, “earth”, etc.) or words that someone uses during scientific research (“look”, “way”, “interesting”). As it was expected, the most used word is “rocks” which constitutes the theme of the project.

Finally, regarding the interactions, there was some feedback given under three investigations but the investigation publishers did not answer back so there was no follow-up discussion. One possible reason is that participants were not notified that somebody had viewed and given feedback on their published investigation. However, two of the interviewees said that *"I have had only a brief look at one or two"* (RH. 6) and *"Yes, but there were not many there - only 7 with notes, 8 with questions, 7 with methods, and 4 with data. Only 3 analysed their data and put conclusions up"* (RH. 11).

4.8.3 Collaboration

Apart from the communication via the 'Inquiry Results', the rock hunters had the chance to collaborate with the other participants through the forum topics and the online chat. As shown from the interaction diagrams (Figure 23), the forum topics and especially the 'question to expert' were the most preferred way of communication. The main arguments from the survey responses supporting the use of the latter are clustered into the following themes: *"precious experience"*, *"direct and creative guidance"* and *"clear points and statements"*. Through these experts could enable non-experts to spend *"less time on web searching"* or *"bibliography reading"*. However, a notable survey finding shows that rock hunters of intermediate expertise preferred to communicate via 'question to expert' more than beginners while the latter chose the online chat as first preference.

Lack of time and flexibility were the main reasons for preferring the forum over the online chat as well as the chance the forum provides to write down more precise questions and answers. Of the rock hunters, 56% had forum as their only communication preference. One of the interviewees said *"the forums and the interactions within it were really useful"* (RH. 7) but on the other hand another interviewee said *"I tried the forum but there was not much action"* (RH. 11). Nevertheless, he added that *"the links from the forum to the rocks diagnostic tool was useful"*. Another interviewee suggested the inclusion of *"a tab showing the new messages a user has not read yet on the forum"* (RH. 14) in order to improve the communication.

Data from the questionnaire and interviews suggest that rock hunters who have used or they would prefer to use chat would use it either to get help in planning their inquiry method or sometimes for social interaction (discussing topics irrelevant to their investigations). Moreover, some of the participants considered one-to-one chat a better way to communicate because not many people express themselves in a public forum. Furthermore, there were some complaints by some rock hunters that even if they wanted to use chat to ask a question (e.g. how to use Google maps), they had to find another way (e.g. Facebook) as the person that they wanted to talk with was not online at that moment. Based on this, a focus group interviewee suggested the integration of “*personal messages*” to make it possible to “*contact people even when they are not available on the chat*” (RH. 6).

Another suggestion by an interviewee was the integration of video and teleconferences to the platform as a more interactive way to communicate with the other rock hunters: “*Somebody may go to the mountain and want to show a rock ad-hoc. They could log on to the platform, start a teleconference and show the rock to the other rock hunters*” (RH. 21). However, this synchronous way of communication, would have the same issues with chat.

Finally, beyond the overall questionnaire results on the communication aspect, an inspection of the nQuire platform logs reveals that intermediate users were socially inactive (with one exception) while beginners and experts were active all over the forum. For example, there are many follow-up discussions on the forum, mainly between experts and beginners, after a question is posted. Thus, the level of expertise affects not only preferences for communication medium but also the type of interaction.

4.8.4 Mentoring

The six experts that joined the community were PhD students or academics/researchers from The Open University. Four of the participants who declared an intermediate level of geology expertise completed a BSc or BSc Hons on Geosciences, Geology or Natural Science, and six studied/are currently studying some Geology-related courses/modules with the OU or other universities.

Finally, of the beginners, one mentioned he had studied some geology courses. However, he felt as a beginner because he had not much field experience. Two others skipped the question; of those, one is an expert in some other field of Environment, Earth and Ecosystems. The rest of the group answered they had either no previous contact with geology or they had geology as hobby. The rock hunters who categorized themselves in the latter group said they like to travel/wander around in nature, observe the environment, read geology books and visit museums.

The level of rock hunters' expertise also appears to affect the role that they take within the project. From the interactions on the nQuire platform, it is noticeable that the dominant interactions are those between experts and beginners. The beginners tended to ask questions and the experts were the ones to answer. Experts assigned to themselves the 'mentor' role as they are willing to give feedback to the participants of lower expertise and also they did not publish any investigation. Conversely, beginners exploited experts' guidance and kept posting questions on the forums. Beyond the two different roles of mentors and the ones who received help, there was also one more role, not that active, adopted by the intermediate rock hunters who were quite discreet regarding their collaboration with other participants. Therefore, although more than half of that group had published investigations, only one had posted on the forums something related to technical issues. Consequently, it may be assumed that intermediate rock hunters count on their own knowledge to conduct their investigation or they are reluctant to share results that may be incorrect or incomplete.

However, based on the survey results, not only the beginners but also the intermediate rock hunters indicated they had received help during their investigations. This may be help coming from the online chat or from a source outside the nQuire platform. This conjecture leads to the question of whether the nQuire community was the main source for help. As shown from the survey results all the choices indicate sources located in or related to the nQuire platform. However, after examining the investigations, other sources come into view such as several web-pages with geology-related material. The use of external (non-nQuire platform) sources was

mostly focused on supporting the ‘collect my data’ phase which was chosen by the beginners as one of the phases with the most help needed.

Moreover, as expected, beginners needed more help than intermediate rock hunters to plan their investigation methods. On the other hand, intermediate users needed the most help in choosing their theme (Figure 28); this may imply that intermediate rock hunters, in contrast to beginners, did not have a theme in mind before entering the project, while beginners had specific questions to which they needed answers and nQuire platform was the place to find them.

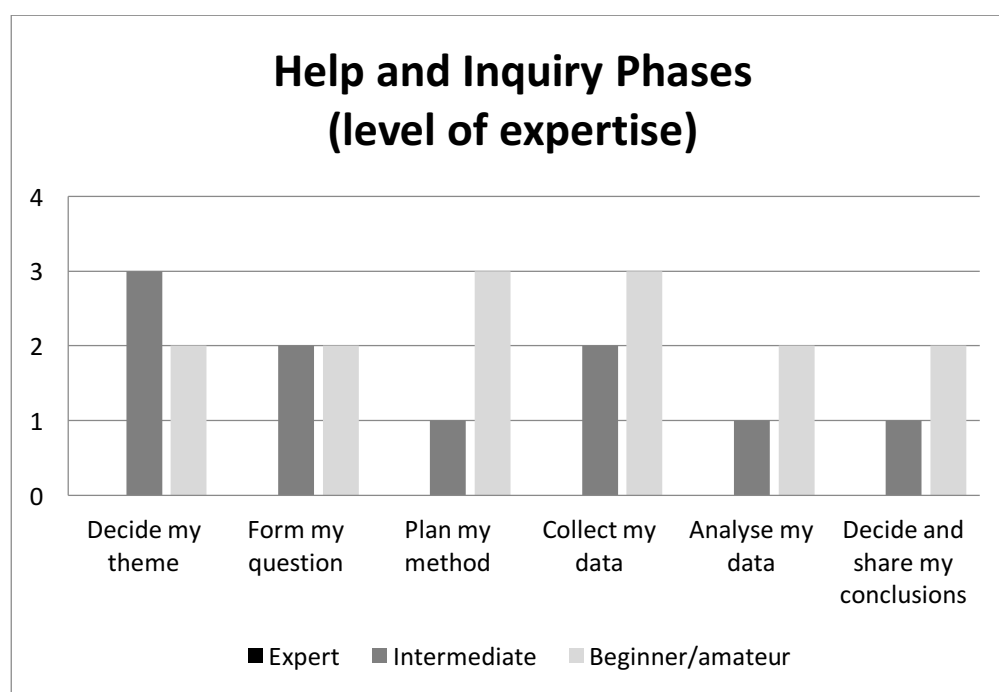


Figure 28: Help and Inquiry Phases - level of expertise

In some of the interviews the responses suggested there were some gaps regarding the collaboration part of the project. In the focus group, the interviewees agreed that they had thought they would have had some better communication with expert geologists:

“I thought we would have some direct help by expert geologists. I wanted to have a better communication with the geologists because I had some difficulties on how to start and I was not sure if I was doing it in the right way.” (RH. 9)

"I thought the same, that once I complete a step, an expert would tell me you did great or you need to change something." (RH. 20)

Based on this observation, the focus group interviewees suggested that joining a group should be one of the things provided, as well as the presence of a trainer offered to guide the participant or a number of participants and answer their questions on a personal level. Another suggestion in relation to the visibility of experts and level of expertise by a survey respondent is the use of rating and badges where *"the experts could vote on each investigation and according to the marks, the non-experts could become for example small researcher or big researcher and then they will also be able to vote"* (RH. 8).

4.8.5 nQuire Platform and Tools

The nQuire platform accommodates tools that support aspects of Citizen Inquiry (i.e. forum, chat, inquiry framework, inquiry results, and scientific tools). The survey respondents found the inquiry framework as the most useful aspect in nQuire with the largest number of mentions. For instance: *"I liked the structure of the site, looking through the diagram. I liked the idea to put it in this way, to visualize the phases of the inquiry"* (RH. 18) and *"the main screen of the platform was for me the picture with the process. Basically this is a really good idea"* (RH. 13).

Another aspect that was considered to be very important was the forum: *"I liked the forum the most from all the aspects of nQuire platform. It offers you direct feedback and a great freedom to write your problems even if you are not familiar with rocks"* (RH. 21). The inquiry results aspect was also seen as important: *"I liked the Inquiry results aspect. Because at the end of my research I could see my work complete and I was happy about it. Because it's your creation and it's a nice feeling!"* (RH. 9).

The rock hunters did not find the nQuire platform very usable: *"It was not totally clear to me, how the whole system works"* (RH. 13). This can be indicated by the SUS score, which was only 60.8%. According to Sauro (2011), who has reviewed 500 SUS evaluations from over 5000 users, the average score from all the 500 studies is 68%, and SUS need to score above 80.3 to reach the

point where the users are likely to recommend the software to other people. In this case, it can be said that the nQuire interface may need some more improvement to become more accessible to the users. Examining the individual results of the SUS, it is indicated that two of the participants found the nQuire platform not easy to use (very low rating). Of those, one mentioned during his interview that he had no relation with technology and struggled when using it. Even so, he had frequent communication with the researcher and the investigation linked to him was completed successfully. The second person, according to nQuire platform data, seemed to have been inactive over the entire project.

The SUS result can also be compared with a score of 66.5% reported by the users of the pilot study from an earlier version of the platform, but the difference between the two scores can be explained by the type of people participating in the two versions of the project. The pilot study project included entirely people from academia (i.e. PhD Students and other senior researchers) while the main project consists of people who are less familiar with new technologies. There are also survey responses from the main study participants who did not have excellent experiences with the technology but used the platform without any problem: *"I found it easy to use, even if I have not the best relation with technology"* (RH. 9).

Although there were some requests for more information on how to use aspects of the platform, the interview data show that after the participants combined exploring the nQuire platform with the tutorial, they found it easy to use: *"without the tutorial I would understand a bit by looking around. But my investigation would be really basic and I would be searching around all the time."* (RH. 20). However, almost all of the interviewees suggested it would be easier for them if the tutorial was integrated into the platform and they could learn how to use each tool:

"The only part I didn't particularly enjoy was not seeing how to use the tools on nQuire" (RH. 6).

"No, maybe by combining the two on the actual site, having a help button or clicking somewhere to give you guidance. Having the tutorial in the diagram would have been great" (RH. 16).

According to the survey results and based on the nQuire platform observations, the most used tools were the image upload tool, the maps and the notebook. There were not many suggestions in the survey responses on what other tools could be added to the platform or how to improve the existing tools but some of the suggestions included microscopes, an integrated rock identification key, a guide for beginners, a list with all the tools and also the option to add PDFs, videos or your own tools. However, some of the participants requested, during the project, whether uploading a video is feasible. When they received a negative response, they either uploaded more pictures or added the video as a link: *"I wanted to add a video but I couldn't, this is why I only added pictures"* (RH. 9). Finally, because of the lack of those and other tools, the participants appeared to use software not included in the nQuire platform, but the possibility of not completing an investigation because of that lack is not mentioned in any survey response and not examined in this study.

Some of the general suggestions mentioned in the survey responses for improving the environment included comments on the interface of the platform: *"the menu buttons to be somewhere easier to find and see"*, *"Perhaps the experts should be a different colour"* and more specific comments on the inquiry presentation and publication: *"a block showing the overview of my inquiry"*, *"just ONE button, press me and your inquiry is published"*. Then, *the inquiry should be posted in a forum or on a central screen so that everybody sees what others are doing"*.

4.8.6 Rock Hunters Experience

One of the survey questions was dedicated to the experience gained by each of the rock hunters from participating in this study. One rock hunter did not gain anything and some others considered there was not enough time for them to gain something. However, most of the responses were associated with the geological and scientific knowledge they had gained through the project – knowledge, methods, tools and websites (Figure 29).

Experience gained in "Inquiring Rock Hunters"

■ Number of Rock Hunters



Figure 29: Inquiry Rock Hunter – What have I learned?

Some examples of the things participants learned are as follows: the different forms of rock transformation, that there is a specific route to conduct an investigation, how and what to look at the rocks in order to identify them, how to organise data, and where to look for resources. For instance:

"I learned that there were useful tools on the web – the one with the rock ID. Also it made me follow a specific route to my investigations: start, hypothesis, plan, collect, etc." (RH. 11).

"I learned stuff about the methodology of research, that some rocks have isolated minerals inside them and they are called metal ores, about the types of rocks. I had no idea on what's happening in earth's depths!" (RH. 21).

Some other participants gained knowledge about local (e.g. the geology of a coast) and daily geology (e.g. shampoos are made of minerals). Furthermore, a couple of responses were related to being a part of the nQuire community and collaborating with new people (e.g. *"learning about rocks can be fun"*). Finally, an expert survey respondent indicated their introduction with the concept of Citizen Inquiry as the experience they earned: *"I think it told me something about teaching. It's a fun way to explain what the rock is"* (RH. 1).

4.9 Discussion - How to support Citizen Inquiry

‘Inquiring Rock Hunters’ was one of the design studies on Citizen Inquiry which form this thesis. The next study was designed and based on the findings and the feedback derived from this study. For this reason, this section presents some implications and observations from this study that influenced the next phase of the design.

4.9.1 Motivations

Rock hunters mainly joined the projects due to personal motivations. Because the project was advertised as a place where people could learn more about rocks in a fun way and answer their questions, most of the participants joined because they wanted to get informed about science and geology or have fun while meeting new people.

Important were also the ‘places’ that the participants were recruited from. Although there was no survey question addressing how the participants learned about the project, responses on another survey question (describe your experience in geology) showed that most of the experts were OU researchers, and a number of intermediate rock hunters attended OU modules in which the project was advertised. However, there is not much information about the beginners’ background. Therefore, a suggestion is

- to survey where the participants learned about the community. This would provide information about efficient places to advertise the project and offer some more data about the participants’ habits and background.

Furthermore, although in general rock hunters were not very active, they remained connected to the community until the end, and contributed to the questionnaires and interviews. The project counted a single drop-out, due to personal reasons. A recommendation that may help explain the relation between motivation and participation is:

- to look for participants’ attitude, satisfaction and identification with the community.

4.9.2 Inquiry-based Learning

The main thing that prevented the rock hunters from completing their scientific investigation (Section 4.8.2) was lack of time, raising the question of whether the time interval of three weeks was insufficient for participants to complete their investigations. The participants themselves did not bring to surface any other reason for being put off finishing the investigation, but the phase completion status which mapped progress, decreased in later inquiry phases. This suggests that the participants may have needed more help in more advanced stages of the investigation. Also, some of the participants seem to face problems with specific phases of the inquiry processes, such as 'analyse my data' (Section 4.8.2). These observations imply there is a need:

- to give more time for the study to run so the participants will have more opportunities to get familiarised with the project's concept and think about their investigation;
- to prepare educational material regarding the steps of the IBL which preferably will be integrated to each inquiry phase or task.

The rock hunters who conducted a scientific investigation were half of the participants (12 out of 24). The participants not conducting an investigation were six experts and six of a lower level of expertise. Investigations published by experts would have been useful examples for the other participants to follow but unfortunately none of them offered that chance. However, it is infeasible to confirm whether they had conducted an investigation and how far they went with it, as publishing the investigation was not mandatory. This again suggests the need for more time and guidance on the inquiry process in addition to the following suggestion:

- to ask experts to conduct and publish scientific investigations, not only for giving an example to the participants of lower level of expertise, but also to benefit from the knowledge of the experts in the community. In this way, the knowledge exchange in the platform will be more advanced and the beginner and intermediate scientists will benefit from such discussions.

The use of geology or science specialised words by rock hunters during their investigations varied according to many factors such as the investigation's completion status, the level of expertise, the length of the text, the background of the participants and the type of the investigation. Therefore there was an apparent tendency by some participants, mostly beginners conducting literature investigations, to copy and paste various digital material instead of using their own language. This 'culture' affects the quality of the investigations and the results of the vocabulary analysis and it is suggested

- to encourage the rock hunters to use their own vocabulary enriched with some specialised words. They could also have been given a glossary related to the theme of the project.

4.9.3 Collaboration

The participants had a slight preference for the forum over the online chat. This happened mostly because of the lack of time they had for using something that requires the synchronous presence of participants on the platform (Section 4.8.3). Some of the participants' comments regarding problems of online chat sparked some new ideas in relation to the addition of new means of communication on the platform. The main idea is

- to create personal profiles for the users that will offer the function of sending personal messages to specific participants. That feature will help to overcome the problem of the synchronous presence on the platform and at the same time will keep the discussion private.

In addition to that, an idea for boosting the "action" (as it was called by an interviewee) in the forums was to publish the investigation on a specific forum category so it will be viewable and more accessible by all the participants. The idea of publishing the investigations on a separate menu as a journal 'Inquiry Results' did not prove as successful as it was expected, as the

participants were not visiting that part of the platform often enough and there was no follow-up conversation in any of the given feedback. So a solution would be:

- to have an easily accessible place on the platform where participants will be able to view and comment on other investigations.

Another thing that would improve the communication and increase the rock hunters' participation on both forums and investigations would be the addition of a reputation system, as suggested by an interviewee. This would work as a motivation for them to collect badges and improve their 'status' on the platform.

4.9.4 Mentoring

As mentioned in previous sections, the role assigned to each level of expertise had a significant impact on their behaviour on the platform. Therefore, the experts took over the role of the mentor, as it was expected, as they were invited to the project as experts. Their role was distinctive, in comparison to the other participants who joined the study without labelling themselves in advance. The drawback of the experts' behaviour was that they assumed they were not required to conduct any investigation. The benefit was that they were willing to play the mentor's role and offer their feedback to the participants. These latter observations raise the idea of somehow including the experts into the project's design and making their contribution to the community more efficient. Some thoughts on that are

- to include volunteer experts in the design of a) the material given to the participants and b) the platform (scientific material, science-related interface, etc.);
- to promote experts on the platform so that the participants will be able to contact and refer to them when they need to;
- to highlight the experts' profiles by adding an identifier next to their usernames;

- to ask the experts to welcome people in person and let them know they can have their help;
- to create groups based on themes having one leader-expert which the participants will be able to join according to their preferences and their investigation topic, and boost their self-confidence through some informative discussions with the experts.

In addition to the mentoring provided by the science experts, it was quite notable that the participants were also seeking help regarding technical issues and they were unhappy that they had to use a tutorial alongside the platform. Suggestions for the supporting of this type of mentoring are:

- to add more instructions available next to the tools and every task;
- to highlight the technology experts or the moderator of the platform as to be more identifiable by the participants.

The above changes aim to make the community stronger and more sufficient and the participants more 'secure' and self-confident within it and as a result to decrease seeking help from outside the community.

4.9.5 nQuire Platform and Tools

The nQuire platform or any other platform used for the implementation of a Citizen Inquiry project should constitute an effective inquiry-based environment able to support the creation and planning of investigations, collaboration with other participants and seeking/receiving help interactions. This section offers some recommendations for the development of the nQuire platform based on the feedback and the recommendations for improvement given by the rock hunters. Some of the suggestions are quoted as examples throughout the findings section (Section 4.8). The overall responses that included feedback, comments and suggestions for nQuire

were coded in four themes and included the following nQuire aspects: nQuire interface, nQuire tools, forum and chat, and Investigations and inquiry results:

nQuire platform interface

One of the most common comment/complaint was related to the usability of the platform. Given the fact that the platform remains the same for the next design study, there are some suggestions on how to improve its usability. A common complaint was about the use of the tutorial together with the platform. This means that rock hunters have to keep both windows open at the same time and search for the tutorial every time they visit the platform. To avoid that, some suggestions are that

- the instructions to be incorporated in the nQuire platform instead of using a separate tutorial document. For instance, the tutorial may be within the inquiry framework with a link along with the task;
- the tutorial to be located in a place where the users would be able to find it when entering the platform, either in the first page or in the top menu as a help button/FAQ so they will be able to refer back to it.

Some other comments focused on how to improve the motivation, mentoring and collaboration aspect within the community by adding some features:

- the use of rating and badges in order to add the element of reputation and expertise, allowing the rock hunters to receive marks and gain a more 'mature researcher' role on the platform;
- the use of a different colour which will be distinguishing the participants according to their level of expertise.

nQuire tools

Rock hunters looked for tools on nQuire and in other places. The lack of some tools on nQuire led the participants to spend less time on the platform, while looking for resources and help outside

the platform. Thus, it is important that nQuire in the future will be able to provide the investigators with more supplies and sustain their participation on the platform. Some suggestions are:

- the integration of geology-related tools, such as a microscope, a rock identification key and a guide/wizard for beginner rock hunters;
- the enrichment of the platform with tools that would improve the investigations and collaboration, such as PDF and video upload.

Forum and Chat

Some of the participants were very willing to communicate and chat with other people. However, not all of them managed to do it successfully due to some limitations (not being able to view unread forum messages or receive chat message when offline). Improvements regarding the ways of communication within the nQuire platform include:

- the option for the users to check whether they have new unread messages on the forum and so they will not be searching the themes one by one for new messages;
- the integration of personal messages that participants will be able to view once they login with the platform.

Both of the suggestions may require the creation of personal profiles, as mentioned in the previous section, that would link the personal and forum unread messages to a specific participant.

Investigations and Inquiry Results

Publishing the investigation could be considered one of the means of communication with the other participants on the platform. Thus, the feature for publishing the investigation should be as easy as

- *“press me and your inquiry is published”* as one participant stated;

Some other recommendations regarding the overview of the investigation by the owner, and the ease of access to other investigations are

- a menu showing the overview of the investigation only to the investigation owner;
- a track of the completed phases on the inquiry framework;
- an announcement of investigation updates on an easily reached place. A suggestion may be a central screen like a news feed page, or a post in a forum as in the Moon Rock Explorer (Villasclaras-Fernandez et al., 2013).

4.9.6 Rock Hunters Experience

The self-reported knowledge of participants showed that they enhanced their science learning and knowledge about the specific field of geology. Guiding them through the inquiry process seemed to be an important element of their learning experience that helped them understand how scientific investigations are done. Thus, a suggestion would be

- to maintain and improve the inquiry guidance element (e.g. inquiry framework) within the platform.

On the other hand, the aspect that was not mentioned frequently in the survey responses was the community experience and fun. Consequently, a recommendation that may improve the community experience and increase participants' satisfaction could be

- gamification techniques, such as badges (as mentioned in Section 4.9.5), competitions and awards;
- to enhance the collaboration and communication between the participants with the enrichment of some community features, such as the creation of more collaborative investigations and easy-accessed discussion.

4.9.7 General observations

In this section there are some final, general observations made by the researcher that are not entirely based on the data analysis findings, rather from her role within the community and some informal comments by the participants:

- More time was needed between the pilot and Design Study 1 in order to implement all the appropriate changes.
- The technology supporting the project should be tested by experts for its usability before its use by participants.
- The creation of a logo for the project was a right decision as it was eye-catching.
- The participants were mostly recruited from OU modules on Geosciences and access to their Facebook groups provided by the OU Geological Society chair-woman was really useful. Even though it was thought that many participants will be recruited via the Geocaching community, none of its members joined the project.
- The presence of six experts in the project was due to a targeted email sent to the OU Geological department. Otherwise the project would have had just a single active expert.
- The project ran for a short time (three weeks) and many participants may have wanted more time to finish their investigations.
- May is a good month for geology, but this is both beneficial and harmful to the level of participation: many of the expert geologists were away on field trips for most of the time.
- The participants thought they would have had some direct help from expert geologists. More information needs to be provided about the experts' role in the project.
- There was no tool showing any new update on the platform and so the rock hunters were missing opportunities for communication, interaction and feedback.
- There was a lack of specialised tools used in geology investigations.

Taking into consideration the above list and based on findings suggestions presented in this section, the next project on Citizen Inquiry was designed to give a better support to the

participants and improve the means of communication in order to create a self-sustaining community with more engaged members.

4.10 Summary

This chapter has described the preparation for and the execution of the first design study.

The Inquiring Rock Hunters project aimed to facilitate citizens to conduct their own rock investigations in collaboration with geology scientists.

The purpose of Inquiring Rock Hunters was to explore the field of Citizen Inquiry investigating some of its particular aspects: motivation to participate, engagement of the participants with the inquiry process, preferable communication tools, roles undertaken by the participants of different levels of expertise, the efficiency of the platform and the tools that support the project and the experience people gained through their participation. The nQuire platform facilitates inquiry-based investigations whilst providing opportunities for social interactions and therefore it was chosen to accommodate Inquiring Rock Hunters. nQuire supplied the Rock Hunters with an inquiry framework with the appropriate inquiry phases, the option to publish their investigation and to send/receive feedback.

Rock hunters were recruited through advertisement on web-pages of education, geology or citizen-science interest. A targeted email was also sent to geology scientists to invite them to offer their expertise to the project. The participants were given tutorials and instructions of different types (videos, text, etc.) to get familiarised with the platform and the tools. Moreover, an exemplar investigation facilitated them to understand how to start and what to add in each inquiry phase. Prior to the launch of the project, a pilot study took place. The participants of the pilot study provided feedback on the functionality of the nQuire tools, the instructions and tutorials, the forum topics and the questionnaire. The detection of some bugs and the participants' suggestions led to some adjustments that improvised the design of the project. Inquiring Rock Hunters project launched with 24 volunteer Rock Hunters.

The main motivation of rock hunters to join the project was their interest in learning more about rocks. Half of the participants created investigations on rocks, and more than half of the investigations were complete. The phase of data analysis was left incomplete by the rock hunters who did not finish their investigations. Beginners used text from geology-related sources increasing their geology-specialised vocabulary. Only three investigations received feedback and there was no follow-up discussion. However, there was some discussion on the forum, mainly between beginners and experts, with 'question to expert' being the most preferred forum thread. The roles within the project were very discrete, with beginners seeking for help, experts providing them with guidance and intermediates being less socially active. The nQuire platform was not found easy to use without the tutorial and it was suggested by the participants that the instructions were integrated in the platform. Additionally, there were requests for including tools necessary for data collection and analysis for geology investigations. Finally, participants gained a wide range of experience, from new scientific knowledge – knowledge, methods, tools – to getting involved in a fun and collaborative community.

The outcomes of the Inquiring Rock Hunters provided feedback on the development and improvement of the nQuire platform and other citizen participation platforms. This feedback has led to some recommendations that facilitated the design of the second study: further investigation on the recruitment based on participants' background and behaviour; design of a study that lasts longer and involves experts in preparing material and exemplar investigations, while actively guiding non-experts in the community and specific groups; integration of field-related (e.g. rock identification key) and inquiry supporting (e.g. glossary) tools to the platform; instantly published investigations that are easily accessible for owners and visitors; improving usability by integrating the tutorial to the platform; use of gamification features (rating, badges, competitions, awards) to enhance participation; creation of personal profiles and communication features (personal messages, unread forum messages) that allow better communication; and finally collaborative investigations that allow easier flow for discussion.

Chapter 5: Design Study 2 – Weather-it

Settings

5.1 Introduction

This chapter describes ‘Weather-it’, which is Design Study 2. Weather-it is an effort to create a sustainable online community for citizens to create and engage with weather investigations. It builds on the results of Inquiring Rock Hunters and other studies on online and citizen participation communities. The design of the study includes three stages: community pre-birth preparations, recruiting participants and engaging the members in the community. The analysis and results of this study can be found in the next chapter (Chapter 6).

5.2 Scope of the study

This section explains the motivation behind the second design study ‘Weather-it’ and the aims of the project.

5.2.1 Motivation

Previous studies have focused on the informal education of citizens and their participation in projects for producing more science. As discussed in Chapter 2, evaluating and improving the engagement and outcomes of communities of public participation in science and other online communities has always been an important topic. To this end there are a number of studies around sustaining online communities that explore different ways of participants’ engagement. These studies explore motivations, and levels and types of engagement within the communities.

However, the results of the above studies, as mentioned in Chapter 2, raise the need for further investigation of the engagement of participants in scientific communities. Furthermore, there are no studies exploring the participation in communities where the members can create their own

investigations and invite others to participate. The first study, Inquiring Rock Hunters, was intended as a first exploratory study on Citizen Inquiry; it is an example of a project where people could start their own investigation on rocks. The outcomes revealed that the community aspect was lacking.

Weather-it constitutes an improved design study that builds on the advice and directions gained by the conclusions of the Inquiring Rock Hunters project. It is informed by more recent studies on engagement and participation.

5.2.2 Aim

This study aimed to explore the creation of an active and sustainable community for citizens around the world to propose, design, manage and share weather investigations. In Weather-it, the participants, of all levels of weather expertise, could create or join weather investigations and invite their social network to join too. The investigations could be weather questions they have in their everyday life (e.g. identify clouds), a phenomenon they want to investigate further (e.g. extreme weather), or something related to climate (e.g. climate change). Joining an investigation, allowed them to add posts and ideas related to the topic, and like or comment on other posts. Additionally, the members could use the forum to discuss their questions and ideas.

Exploring the Weather-it community aims to answer the research question: “How can we create an active and sustainable online community for citizens to engage with scientific investigations?”. In particular, the target is to explore aspects related to the creation, maintenance, engagement, inquiry and science taking place in the community (Table 9 – Section 3.6). It addresses the following questions:

RQ1: How can we create a sustainable and active online community for Citizen Inquiry?

RQ2: How can Citizen Inquiry engage members of the general public with investigations?

RQ3: How can Citizen Inquiry participants adopt an inquiry process that follows good practices of science learning?

The expected outcomes included increased engagement in a community of gradually growing participation as Citizen Inquiry allows lay people to start investigations of their choice, based on their personal experience of everyday science.

5.3 Weather-it Community Design

The preparation of the Weather-it project followed these steps: the selection of a platform suitable to accommodate a community of collaborative scientific investigations on weather, the designation of some community requirements to support the aim of the community, the preparation of exemplar investigations, and the evaluation of tools used for the investigations.

5.3.1 nQuire-it Toolkit

The nQuire-it toolkit, which was only developed after the end of ‘Inquiring Rock Hunters’, was selected to host the Weather-it project as it originates from the idea of having citizens act as scientists by allowing them to initiate, manage, share and complete crowdsourcing projects of their own interest (Herodotou, Villasclaras-Fernandez, & Sharples, 2014). Furthermore, as it is a project hosted by The Open University, it was a convenient choice for having access to (a) the Google Analytics site (for monitoring the everyday traffic) and (b) the database log files (for retrieving useful data for the analysis). nQuire-it was preferred over nQuire as the latter was initially built to support school science with the guidance of a teacher, while the nQuire-it toolkit reflects the needs of a community where citizens and scientists collaborate.

The toolkit builds on previous work in online personal inquiry learning (Sharples et al., 2014) and proposes that implementing personally meaningful science investigations may lead to greater engagement. It consists of the nQuire-it web platform³⁴ (Figure 30) and the Sense-it Android app³⁵ (Figure 31).

³⁴ www.nquire-it.org

³⁵ <https://play.google.com/store/apps/details?id=org.greenin.scientoolkit>

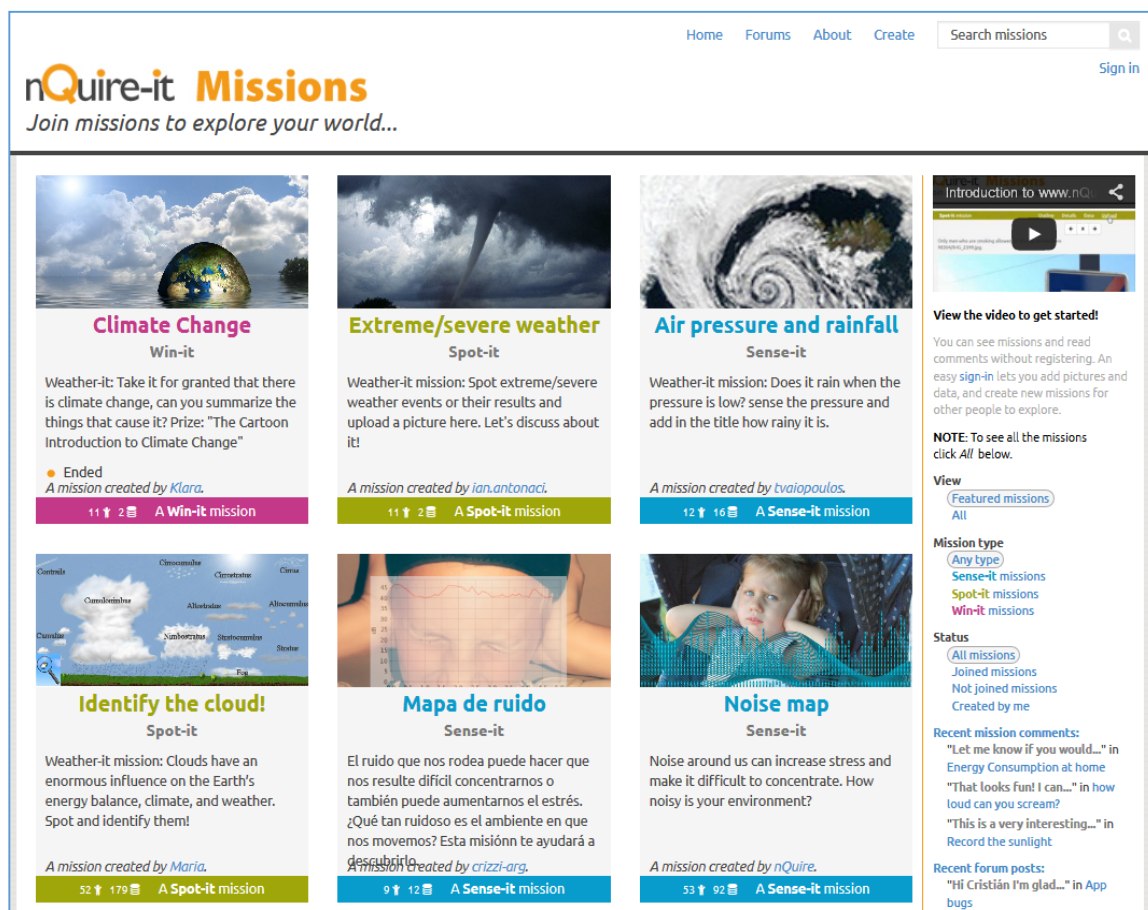


Figure 30: nQuire-it platform

The nQuire-it platform, itself open source software, promotes openness in multiple ways by allowing the extension of its code and content, and by offering citizens with opportunities to initiate and lead their own investigations, supported by open collaboration with other members.

Open source software: The importance of open access tools in the field of science process has been emphasized (Förstner et al., 2011). The source code for the nQuire-it platform and Sense-it app is available³⁶ for modification and distribution and thus one can re-use and extend the software. For the toolkit design, students (aged 14-16) and staff from UK Sheffield University Technical College collaborated with the researchers, proposed their ideas and then evaluated the software contributing to its improvement and functionality with their suggestions (Herodotou et al., 2014). Using the nQuire-it for this study allowed colleagues to access the code and make changes for the purposes of Weather-it.

³⁶ <https://github.com/nQuire>

Missions: In order to support the creation of online personal inquiries by lay people, the nQuire-it platform provides three different types of investigation (called ‘missions’ on the platform), according to the method of data collection, along with exemplar inquiry missions for each type that aim to illustrate the inquiry process. Initiating a mission is facilitated by visual conceptual organisers that assist creators in naming and describing their investigations, numbering the goals of their mission, providing instructions for taking part in the project, and selecting the methods of data collection (sensors, images, text) from the available tools. The three types of mission that nQuire-it platform supports are:

1. Sense-it missions: the data collection process is facilitated by the Sense-it app (Figure 31) which activates the existing sensors of Android smartphones and tablets (e.g. pressure, humidity, sound, light, etc.) and allows users to record, visualise, save and download the log files. Moreover, the user profiles and missions are connected to nQuire-it and thus Sense-it uploads measurements to the website automatically. The Sense-it app can be found in Play Store.
2. Spot-it missions: the users may capture images and spot things around them. These uploaded pictures constitute the collected data for Spot-it missions. This type of mission can be used for identifications.
3. Win-it missions: the users set challenging questions which require text as an answer. The questions may involve science experiments and the answers should be creative as the process includes rating of each response.

Some of the missions may be open-ended and some others closed-ended. For example, a Sense-it or Win-it mission may have a specific question and people help in finding the answer through their recordings or answers. A Spot-it mission may have an open question that inspires people to start their own investigation under the specific topic and in turn they invite other participants to help them answer their question.

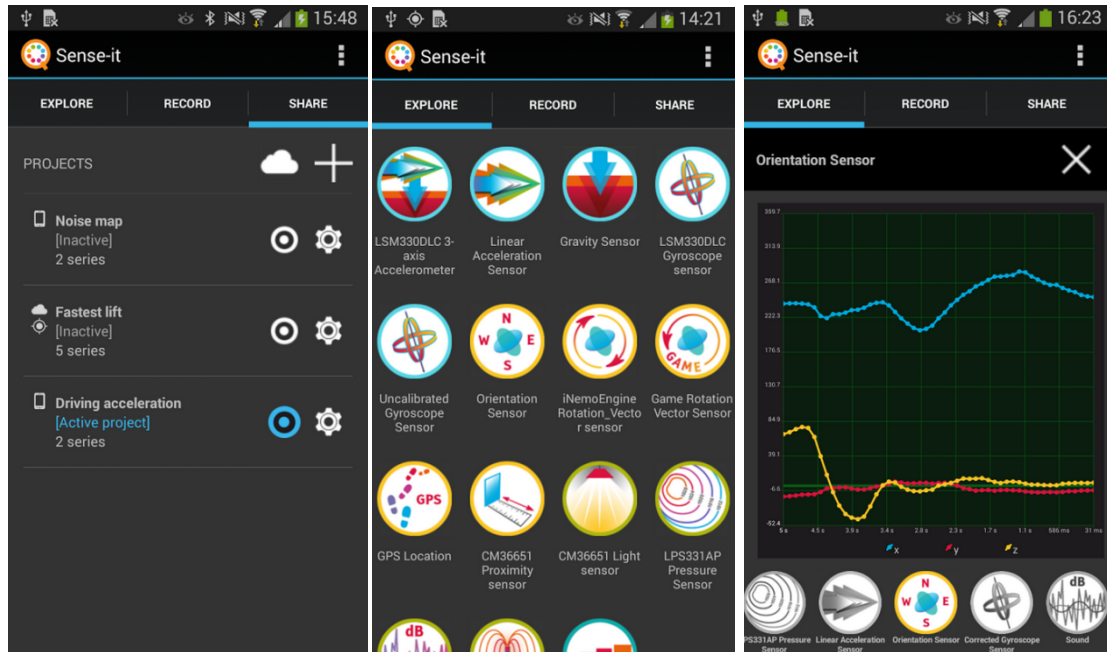


Figure 31: Screen displays from Sense-it Android app at Google Play

In addition to the missions, nQuire-it also hosts a forum for further discussion which can be connected to a specific mission through a link to a discussion forum topic.

Open content: Citizen science may not necessarily be open science as many projects share data but may not make the full research process public (Wiggins & Crowston, 2011). However, the nQuire-it missions provide open and public access to all the inquiry stages. The missions initiated by lay people, as in crowdsourcing, make an open call for contributions from members of the nQuire-it platform and beyond the platform, to both scientists and non-experts. The content includes geo-tagged sensor records with Google mapping technology to allow people to identify where the measurements took place and filter these using author, date and votes tags, as well as tags related to the types of data collected. Moreover, users for Spot-it missions upload their own pictures with important information in the title describing place, time, etc. Finally, the contributions in text form (comments, win-it responses, forum posts) are open access material and a means for anybody who wants to reflect, draw their own conclusions on the missions and discuss their results with others. The missions in this way represent a type of distributed scientific collaboration, with contributors from different backgrounds and levels of scientific expertise.

Engagement: nQuire-it engages lay people and scientists in an ‘open collaboration’ model (Vreede et al., 2013), by which the mission tasks set by the owner are completed due to the synthesis and combination of multiple contributions from the members, utilizing in this way ‘collective intelligence’ (Suriowecki, 2005). Therefore, the process is open to all users, not just to the mission owners. The members have interactions between them to improve one another’s contributions instead of competing. An example of this open collaboration is the identification process in the Spot-it missions: the owner shares a picture of interest (such as an unusual cloud formation for an ‘Identify Clouds’ mission) and invites the members to contribute towards its identification. The Spot-it process has some similarities to the iSpot platform (Scanlon, Woods & Clow, 2014) – except that with nQuire-it, members of the public can propose a broad range of topics for investigation. Members with different and sometimes conflicting ideas and opinions, can then discuss with each other and provide feedback on the topic. Such involvement in the collective effort towards the missions paired with the enthusiasm on the topic can usually indicate engagement in the community (Bobek et al., 2009).

5.3.2 Community Requirements

The results from Design Study 1 showed that there was a low sense of belonging to the community. In this section, requirements for building a successful community are described, which may improve the sense of community and facilitate engagement in the Weather-it project. This survey of the community requirements aimed to address RQ1, where the implementation of those features allowed the exploration of their impact on the success level of the creation and sustaining of the community.

5.3.2.1 Survey on design features

For the creation of a list of community requirements, the following were investigated:

1. Literature on online communities and Social Networks/other communities: Features from other social networks and citizen participation communities were investigated (Sections 2.5 and 2.6).

2. Design of existing weather communities: Two popular weather communities/platforms (UK Weather Watch (A), Netweather.tv (B)) and four Weather citizen science projects (Weather Detective (C), Old Weather (D), WeatherSignal (E), wezzoo (F)) were surveyed and their individual design features were gathered together. Then, these features were summed up for all the platforms/communities and organised in the following seven categories: the community topic (weather), the tools, the members, the communication between the members, reputation systems, networking, and communication of the project outside and inside the platform (Table 17).
3. Community needs: Aspects that serve the creation of a Citizen Inquiry community that engages the public with weather investigations (Section 5.3.2.2.).

Table 17: Design of existing weather communities

CATEGORY	DESIGN FEATURES WITH WEATHER PROJECT/PLATFORM CODE	
WEATHER	current weather (A), link to Met Office (A), flood warnings (A),	learning centre (A), link to webpages (A), link to live streams (B)
TOOLS	basic & video tutorials (C, D), gallery (B), list of items/investigations (D),	difficulty ranking (D), data collection (D, E, F), data demonstration (E, F)
MEMBERS	personal profile (A, B, D, F), calendar/birthdays (A, B), new members (A), members list (A, B, D),	online members (A, B, D), locate members (A, B), friends/follows (A, B, F)
COMMUNICATION	personal messages (A, D), forum (on/off topic) (A, B, D), subscription to forum/blogs (A, B, D),	status updates (B), project team/volunteers contact (C, D, E, F)
REPUTATION	reputation points/likes/thanks (A, B), reputation demonstration (B), roles (A, D),	badges (F), tangible prizes (C), leader-board (F)
NETWORKING	connect via social network (F), project pages on social networks (C, E),	blogs, (B, C), share posts on social networks (B, E)
PROJECT	about (A, C, D, E, F), F.A.Q (A, C),	website analytics (B, C)

5.3.2.2 Weather-it community requirements

The survey led to the creation of a list of requirements for the Weather-it community. In addition to the survey, a number of requirements focus on the scope of the project (e.g. create/join a mission). Some of the requirements are already covered a priori by the design of the nQuire-it platform. The rest of the requirements are divided into essential, valuable and nice to have, according to their importance to the project:

Existing nQuire-it design

- Attractive **professional look**: This is a significant motivation for the users to join it (Fogg, Soohoo, & Danielson, 2003) and use it (Heijden, 2003). The buttons should all be **findable** (big, bold, with images or menu-like) at the home page.
- **Create a profile** (username, photo, and country/town). Wenger (2001) argues the importance of the individual identity in a social learning system. The users should be able to express their individual personality in the community with the personal information and their pictures, so as to reflect their identity (Andrews, 2002) and be perceived as real people in mediated communication (Garrison & Arbaugh, 2007).
- **Sign in by using existing username of other platforms**. The integration of the community with other sites, making the users' registration easy and fast by using their existing user identifiers (e.g. Figure 32).

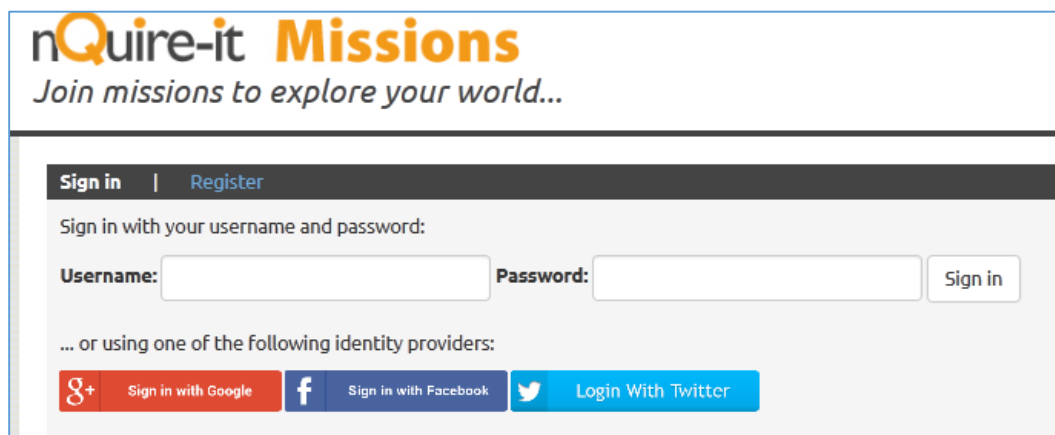
The image shows a web form for 'nQuire-it Missions'. At the top, the logo 'nQuire-it Missions' is displayed in orange and black, with the tagline 'Join missions to explore your world...' below it. The form has a dark header bar with 'Sign in' and 'Register' links. Below this, it says 'Sign in with your username and password:'. There are two input fields: 'Username:' and 'Password:', followed by a 'Sign in' button. Below the password field, it says '... or using one of the following identity providers:'. There are three buttons for social login: 'Sign in with Google' (with a Google+ icon), 'Sign in with Facebook' (with a Facebook 'f' icon), and 'Login With Twitter' (with a Twitter bird icon).

Figure 32: nQuire-it – sign in form

- **Search** a mission

- **Join** a mission
- **Start** a mission
- **Comment** on data (Figure 33)

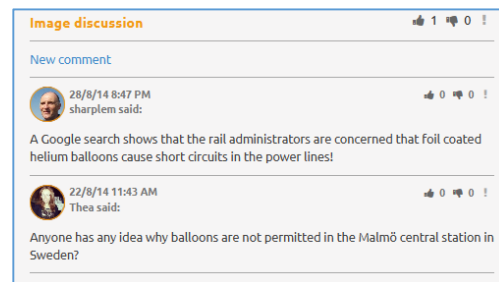


Figure 33: nQuire-it – comment

- **Content sharing system** in external platforms (Facebook, twitter, email). Exporting of content will increase the visibility of the community among the social networks of members (Resnick & Konstan, 2012).
- **Reputation system** (Rating/Like): the members should be rewarded for their efforts (Iriberry & Leroy, 2009). In nQuire-it, the current rewarding system is receiving of likes (Figure 34).

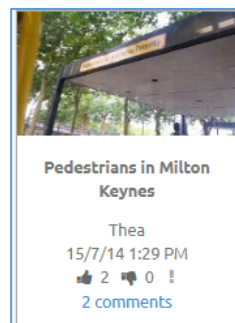


Figure 34: nQuire-it – thumb up

- Link to the **forums** to join the platform forum **discussion** (Figure 35)

Forums			
Forum	Last post	Threads	Posts
nQuire-it			
<ul style="list-style-type: none"> Bugs, feedback and suggestions 	Welcome! 7/7/14 3:57 PM by evilfer	1	1
Missions discussion			
<ul style="list-style-type: none"> Noise map 		0	0
<ul style="list-style-type: none"> Weird signs 		0	0
<ul style="list-style-type: none"> Bee inspired! 		0	0
<ul style="list-style-type: none"> Fastest lift 		0	0
<ul style="list-style-type: none"> Midnight stroll 		0	0
<ul style="list-style-type: none"> Computer loudness test 		0	0
General discussion			
<ul style="list-style-type: none"> Introduce yourself 		0	0

Figure 35: nQuire-it – forum

- **Archive list** with all the weather investigations or by specific type
- **Location** for weather investigations that require geographic coordinates for the data collection

Essential

- **Notifications** will support and reinforce the participation and contribution of the members in the community (Kraut & Resnick, 2011).
- List with **recent** weather investigations: this will help the newcomers to find the most active investigations more easily and join the discussion straight away (Resnick & Konstan, 2012).
- **News feed:** displaying the prominent user-contributed content, conveys activity within the community (Resnick et al., 2012).
- **Personal Message:** join a private asynchronous discussion (may be synchronous if both users are online). The members should have personal conversations in order to build relationships (McKenna et al., 2002) and increase the sense of co-presence (Slater et al., 2000). Also, off-topic communication is preferred for enhancing the interpersonal interaction (Postmes & Spears, 2002).

- **Top posters:** performance feedback, which builds a comparative atmosphere, may have a positive effect on the motivation of the members for contribution (Locke & Latham, 2002).
- Most **popular Investigation** (Likes/thumbs up) as a displayed performance feedback which affords status reward for the quality of contribution and may motivate participation (Kraut et al., 2012)
- Who is currently online (e.g. Figure 36): increases the visibility and social presence aspect of the platform and gives a sense of who else is active (Preece, 2000). Social presence leads to increased interaction (Beuchot & Bullen, 2005) and engagement (Brown, 2001).

There are 3 registered users and 0 hidden users online
 There are 9 guest users online • Display guests

Page 1 of 1

USERNAME	FORUM LOCATION	LAST UPDATED
Storm	Viewing who is online	Tue Jun 17, 2014 5:07 pm
Baidu [Spider]	Reading topic South West Snow Watch Community in Weather Chat	Tue Jun 17, 2014 5:07 pm
Bing [Bot]	Viewing topics in Technology	Tue Jun 17, 2014 5:06 pm

Legend: Helper, Honorary Member, Management Team, Moderator, Partners

Figure 36: UK weather watch – who is online

- **Invitation** to external members to attract friends to the community (Resnick et al., 2012) (e.g. Figure 37). This may be done by recruiting existing social ties of members through other Social Network services (Ren & Kraut, 2012).

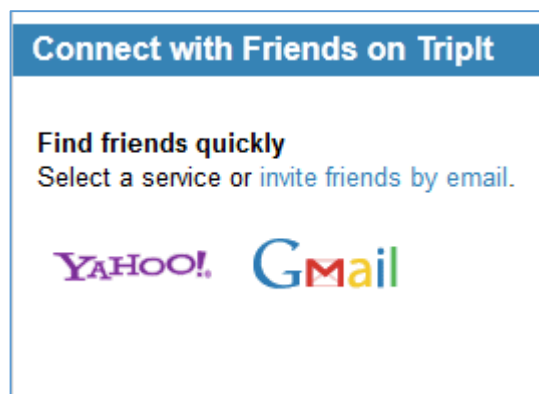


Figure 37: Triplt – invite friends by email

- Visit other users' profiles to increase the sense of co-presence (Slater et al., 2000).

- **Web analytics/admin table:** a tool which will trace and demonstrate (to the moderator) daily/weekly the number of memberships, the number of posts in the forums and the missions, and the percentage growth of those. These indicators will also be used to raise the success expectations and reduce the potential of community turnover (Resnick et al., 2012).
- Space for **video-tutorial ('about')** to introduce new users to the platform.

Valuable

- Link to a **Members List:** demonstrating the members list will help in increasing the social presence in the community.
- **Add friends:** adding a friend may enhance the bond-based commitment as the members come close to other members.
- Give **feedback** in every step of the mission (comment, like, rate). E.g. one can comment/respond on a mission or comment on a comment of the mission. Interaction with other people can keep the members motivated to the community (Kubey & Csikszentmihalyi, 2013).
- **Badges** (e.g. Figure 38): given for particular contributions to the platform, such as performing a certain number of actions of a given type (Anderson et al., 2013).

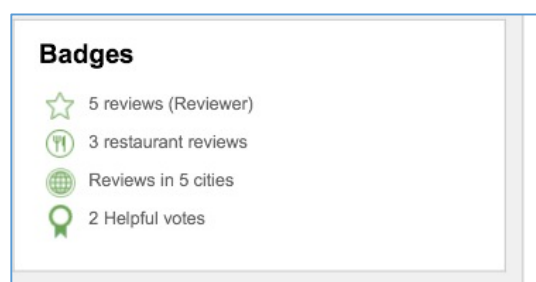


Figure 38: Trip advisor badges

In the current project it could be, for example:

- Commander (started more than 5 missions)
- Leader (started more than 3 missions)

- Ambassador (Invited more than 3 people)
- Tracer (joined more than 3 missions)
- Prosperous (received more than 10 likes)
- **Invitation to internal members** (investigation) (e.g. Figure 39).

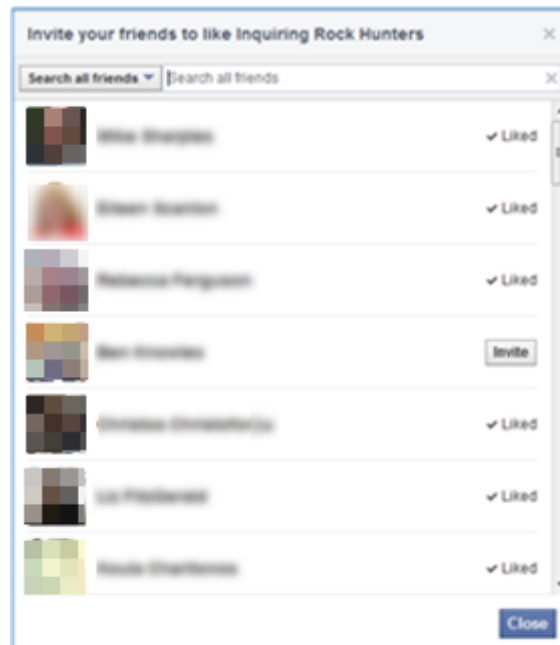


Figure 39: Facebook – inviting friends to join the investigation

- View **contact list of moderators** (names linked to personal message) (e.g. Figure 40). The members and especially the newcomers will be able to reach and contact the moderators more easily.

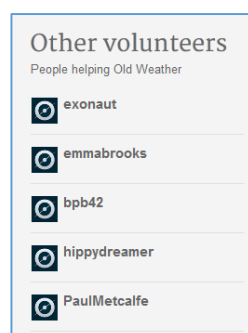


Figure 40: Old weather – team contact list

Nice to have

- Link to **members' location map** which will show the location of the users in UK or Europe (e.g. Figure 41) and enhance the social presence:



Figure 41: UK Weather Watch – members' location map

- Demonstrate **new members**: keeping the newcomers around is important for the survival of the community after membership turnovers. Therefore, newcomers should be encouraged to reveal themselves and old members could have welcome responsibilities (Kraut et al., 2012).
- 'Current weather' application (e.g. Figure 42):



Figure 42: UK Weather Watch – current weather

- Link to calendar with **members' birthdays**, and other events (added only by moderators) (e.g. Figure 43). Displaying members' birthdays may reinforce bond-based commitment and make members feel close to other members.

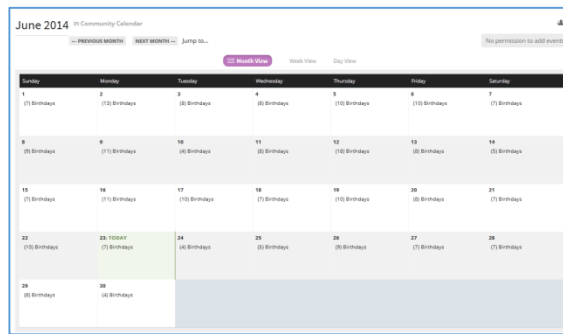


Figure 43: Netweather.tv – calendar

- ‘Reader-to-leader’ funnel (Preece & Shneiderman, 2009) (Figure 44). The new member may progressively move to have a more important or leading role within the community, such as helper or moderator.

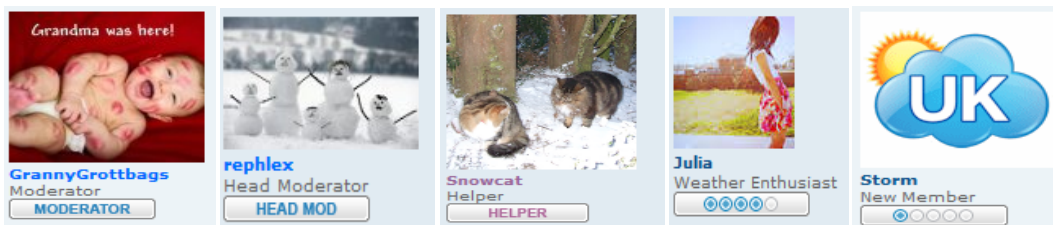


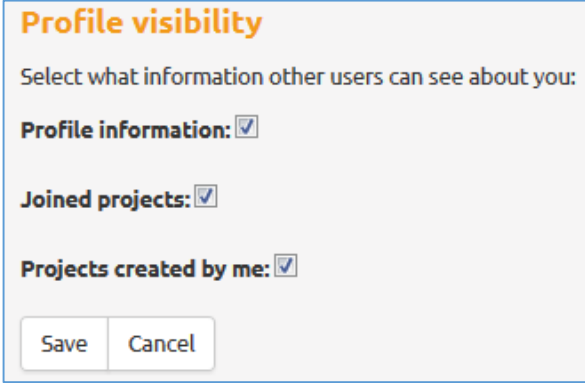
Figure 44: Member status in UK Weather Watch

- **Subscription:** the members can receive emails with updates after subscribing to a mailing list. The members will be able to contribute if they are aware of the needs and the content of the community (Kraut & Resnick, 2011).
- A ‘**Weather Learning Room**’ forum to learn about the weather

5.3.2.3 Requirements applied to nQuire-it

After the list with requirements was set up, only a subset was implemented on the nQuire-it platform, as the time and resources were limited. The applied features were mainly drawn from the list with the essential requirements or emerged as urgent for the flow of the community and investigations. The implementation was carried out by the nQuire-it development team at the Institute of Educational Technology of The Open University, based on the requirements for this project. Those were mainly retrieved from the list with the essential features:

- The investigations displayed on the main page of nQuire-it were sorted by the most recent ones and thus members were able to spot the most active investigations.
- One could click on a member's name in order to visit their profile page and learn more about them: name, location, description, interests and which projects they have joined and created. The members could decide about the degree of privacy for their profiles (Figure 45).



Profile visibility

Select what information other users can see about you:

Profile information: ☒

Joined projects: ☒

Projects created by me: ☒

Save Cancel

Figure 45: nQuire-it profile visibility

- A list at the right sidebar was added displaying who is currently online in order to increase the visibility and inform the members about who else is active.
- One of the nQuire-it moderators uploaded to the right sidebar a video-tutorial explaining the basics about the platform.
- A feature that was not included in the requirements list but was spotted later was merging the accounts created through nQuire-it and Sense-it. This helped to prevent the existence of two usernames for the members who were using both the mobile application and the platform. Furthermore, the members could connect their nQuire-it profile with profiles in other Social Networks (i.e. Google, Facebook, Twitter) (Figure 46).

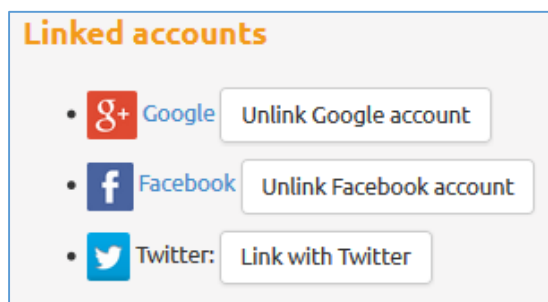


Figure 46: nQuire-it linked accounts

- Another feature which is considered significant for a community of scientific investigations, and was added afterwards to the nQuire-it platform, is the option for downloading the collected data in a spreadsheet to make the data analysis easier. A button to download the data in CSV format was made available below the list of collected data.
- Finally, a mailing list, which was a “nice to have” feature, with all the members subscribed was implemented in order to inform about the community updates.

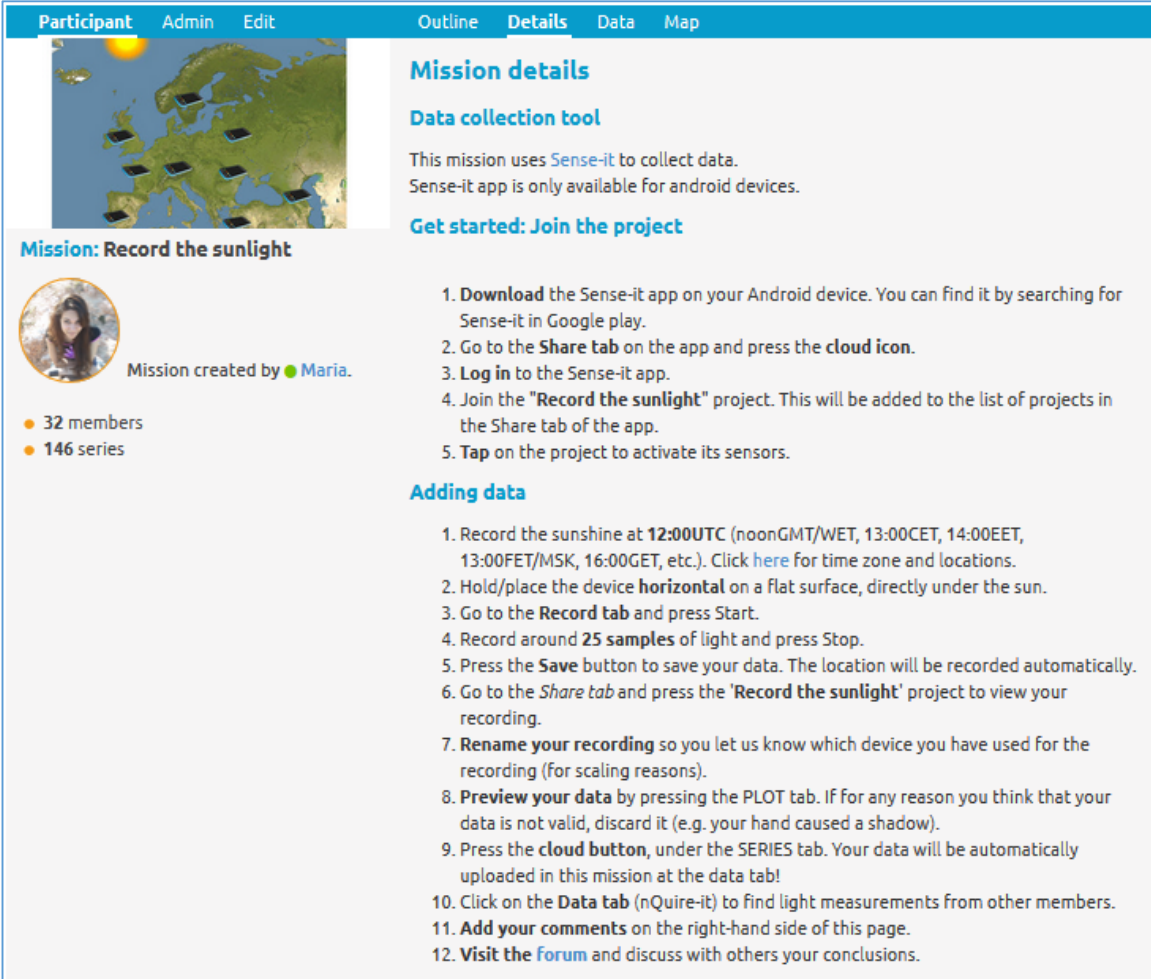
Alternative techniques were sought for some other important features that could not be implemented on the platform for this project. These are described in Section 5.5 and include notifications to the members for any feedback received on their posts, tangible awards and prizes (instead of badges) for particular contributions, and notifying members through a mailing list (subscription) and other means about the updates and needs of the community.

5.3.3 Setting up the exemplar missions

In order to set up the weather missions, external help was sought from a weather expert. The aim was to create a mission of each type for the first members to join and start their investigations and to be used as examples for the creation of other missions, as recommended in Design Study 1 (Section 4.9.2).

For the Sense-it mission, the light sensor was the most practical to use as it can be found in nearly all mobile devices and thus more participants would be able to join and contribute to the particular mission. The suggestion by the expert was the creation of a mission ‘Record the

sunlight' for measuring and comparing the sunlight in different parts of Europe (Figure 47). The expert enriched this idea by adding details to the mission, such as specific recording time, methods for recording the sunlight and suggestions on how the results can be used and analysed.



The screenshot shows a web interface for a mission titled "Record the sunlight". At the top, there are tabs: "Participant", "Admin", "Edit", "Outline", "Details" (which is active), "Data", and "Map". On the left side, there is a map of Europe with several smartphone icons indicating data collection points. Below the map, it says "Mission: Record the sunlight" and shows a profile picture of a woman with the text "Mission created by Maria." and statistics: "32 members" and "146 series". The main content area is titled "Mission details" and "Data collection tool". It states: "This mission uses Sense-it to collect data. Sense-it app is only available for android devices." Below this, it says "Get started: Join the project" and lists five steps: 1. Download the Sense-it app on your Android device. You can find it by searching for Sense-it in Google play. 2. Go to the Share tab on the app and press the cloud icon. 3. Log in to the Sense-it app. 4. Join the "Record the sunlight" project. This will be added to the list of projects in the Share tab of the app. 5. Tap on the project to activate its sensors. Below this list, it says "Adding data" and lists twelve steps: 1. Record the sunshine at 12:00UTC (noonGMT/WET, 13:00CET, 14:00EET, 13:00FET/MSK, 16:00GET, etc.). Click here for time zone and locations. 2. Hold/place the device horizontal on a flat surface, directly under the sun. 3. Go to the Record tab and press Start. 4. Record around 25 samples of light and press Stop. 5. Press the Save button to save your data. The location will be recorded automatically. 6. Go to the Share tab and press the 'Record the sunlight' project to view your recording. 7. Rename your recording so you let us know which device you have used for the recording (for scaling reasons). 8. Preview your data by pressing the PLOT tab. If for any reason you think that your data is not valid, discard it (e.g. your hand caused a shadow). 9. Press the cloud button, under the SERIES tab. Your data will be automatically uploaded in this mission at the data tab! 10. Click on the Data tab (nQuire-it) to find light measurements from other members. 11. Add your comments on the right-hand side of this page. 12. Visit the forum and discuss with others your conclusions.

Figure 47: Sense-it exemplar mission – Record the Sunlight

For the Spot-it mission, observing clouds seemed to be the best option as it could engage non-experts. Rather than just looking for funny shapes, the participants had to spot, take, upload a cloud picture and name the cloud type. For naming the cloud type they were given a cloud-spotting guide by the Met Office³⁷. Creating a mission 'Identify the cloud' should provide participants the opportunity to start their own investigation by posting a new cloud and spark discussion around it, in relation to its identity and influence on the weather (Figure 48).

³⁷ <http://www.metoffice.gov.uk/learning/clouds/cloud-spotting-guide>

ParticipantAdminEditOutlineDetailsDataUpload

Mission: Identify the cloud!

Mission created by ● Maria.

- 55 members
- 182 images

Leave mission

Weather-it

This is a Weather-it mission. Please don't forget to complete the [consent form](#) (if you haven't done so already) and help me with my PhD project. Thank you!

Clouds have an enormous influence on the Earth's energy balance, climate, and weather (Nasa Aeronautics and Space Administration). Their importance for the everyday weather and global climate is significant. Should we give their presence a second thought?

Spot and identify them. To do so, use the [Cloud Spotting Guide](#) (Met office) or ask for help from the community.

For further discussion, go to the forum topic "[Identify the cloud](#)"

**The front cover image is a work of the United States Department of Energy (author: Christopher M. Klaus) and it belongs to the public domain.*

***Please make sure you have permission to use any images you upload. It's better to use pictures you have taken yourself, rather than found on the web.*

Figure 48: Spot-it exemplar mission – Identify the cloud!

As Win-it missions require additional effort to be answered, the experts were asked to provide some interesting questions that could not be answered just by a web search. The question that was chosen as a Win-it exemplar mission was “*Why do you get colder going up a mountain on Earth, but you wouldn’t on Mars?*”. The goal of the mission ‘Earth Vs Mars’ (Figure 49) was to familiarise the participants with the climate in Mars and how it differs to Earth’s climate. The final answers should include description of the research method, data and their resources.

The screenshot shows a web interface for a mission titled "Mission: Earth Vs Mars". At the top, there are tabs: "Participant", "Admin", "Edit", "Outline", "Details", and "Ideas". The "Outline" tab is selected. On the left side, there is a header image showing Earth and Mars. Below it, the mission title "Mission: Earth Vs Mars" is displayed. A circular profile picture of a woman is shown next to the text "Mission created by Maria". Below this, a list of statistics is shown: "Ended", "24 members", and "4 ideas". A "Leave mission" button is also present. The main content area on the right is titled "Mission outline" and features the "Weather-it" logo. It contains a paragraph of introductory text, a bolded question "Why do you get colder going up a mountain on Earth, but you wouldn't on Mars?", and several paragraphs of explanatory text. At the bottom of the main content area, there is a section titled "Mission status" which states "This mission is waiting for the winner decision!" and a link to "See all ideas".

Figure 49: Win-it exemplar mission – Earth Vs Mars

The exemplar missions were created and reviewed by the expert prior to their publication.

5.3.4 Light Sensor Calibration

An important issue was the calibration of sensors. Inaccuracy and improvements of sensors on mobile devices have been reported in the past. For instance, Blum, Greencorn and Cooperstock (2012) when investigating the compass and gyroscope sensors detected mean location errors of 10-30 metres and compass errors around 10-30°, with high standard deviations for both. Similarly, Hemminki, Nurmi and Tarkoma (2014) detected inaccuracy of the gyroscope and accelerometer and worked successfully towards the improvement of these sensors.

Likewise, prior to the creation of the 'Record the sunlight' project, trials took place to test whether the light sensors on mobile phones were correctly calibrated. A first step involved measuring the light of a halogen 42 watt bulb with plain glass, bought new and suspended on a wire with no shade and no other ambient light in the room. Eight different types of mobile device were placed flat, directly under the light bulb and about 1 metre away, and recorded 20 samples of light, repeating the measurement three times. An approximation to the theoretical illuminance

of the particular light bulb at that distance was calculated with the inverse-square law ($\text{Illuminance} = \frac{\text{luminous flux}}{\text{area}}$) to be equal to 66.85 Lux. The results showed a wide divergence of measurements ranging from 33 to 1000 Lux. The conclusions from this experiment were that there was large discrepancy between the theoretical Lux and the measurements. Furthermore, there were differences among the mobile devices of the same brand and model. These led to a more thorough investigation involving the help of experts.

First, advice was sought from a calibration expert. One method proposed for calibrating the application, was to add a scaling feature to the software, allowing the user to increase or decrease the level by reference to a calibrated professional light level meter. Shortcomings in using this method were the absence of such a scaling feature on Sense-it app and the use of the application by people without access to a professional meter. Yet, a professional light meter was used by the researcher as a test to calculate the difference between the measurements by several mobile devices and a calibrated sensor.

Then, a camera expert was contacted for further investigation. As scaling between devices was one of the possible options, device datasheets were studied in order to provide information such as integration time and wavelength response. Some of the mobile devices used in the experiment had linear sensors in them, which means that if the light input doubles, the output will also double (in some other cases when the input doubles the output quadruples). For such linear sensors, a scaling relation may work as long as the scaling is done for the same light source between devices and not between a halogen bulb and sunlight. This inability is due to the possible difference in wavelength responses.

However, the light sensors on some phones only output a limited number of levels since they are used primarily for dimming the screen in sunlight rather than giving accurate Lux readings. Moreover, some sensors have 'max' values, beyond which they will not be sensitive to any increase in Lux, and this may be an issue when measuring bright sunlight. Another important factor affecting the measurements is the tolerance associated with particular sensors which may

relate to the uncertainty of the output of the chip for a given light input. For example, a device sensor may have a tolerance of +/- 15% varying the results compared to other devices. Finally, hardware damages (e.g. scratched/dirty monitor or lens) may also affect the measurement values.

Despite the above credibility issues, the light sensor was used for the Record the Sunlight mission (a) as a means to engage members with the process of collecting data with a sensor (method and quality of plots) and (b) to collect recordings for further research on the calibration and credibility of the light sensor with the help of an expert. Similar to NoiseTube project (Maisonneuve et al., 2009), contradictory or similar measurements from the same area and/or device may help to improve the system.

5.4 Core Group

The 'core group' plays a vital role in the success of the community, and all new members are potential members of this group (Young, 2013). At the beginning of the project, a group of ten people interested in weather (science experts and non-experts) was recruited from around Europe to form the core and start of the community. An open invitation was posted on Facebook and Twitter and circulated by email, and it was inviting people interested in weather to join the core group. The core group members included two weather experts and eight non-experts, located in Switzerland, Georgia, Turkey, Greece, Belgium, U.K., Sweden and Spain.

The target of the core group was to test the exemplar missions and activate the community before other participants arrived. Thus, they were given instructions and a number of activities they could do on a daily basis:

- Join and contribute to the existing three weather missions
- Create new missions
- Contribute to the forum discussion
- Provide feedback on the nQuire tools and the project
- Share the project with their networks

In this way, some activities and discussions were ready for the first members to join. Concurrently, with the invitations to their social networks they were also asked to support the newcomers. The core group members were given £20 Amazon coupons as reward for their help.

5.5 Engaging the participants

Engaging the participants in the community is one of the big challenges all online communities face. This section describes the techniques used for sparking and sustaining participation in the community.

5.5.1 Researcher as moderator

According to Salmon (2012) the essential role of the e-moderator in an online learning community is to promote human interaction and communication through the building of knowledge and skills. Other research attaches to the online moderator of informal online learning communities a combination of roles, such as technical trouble-shooter, hostess, educator, organiser and facilitator (Mason, 1994; Berge & Collins, 2000). Moreover, participants of an online community of practice refer to the moderator as *“being the one who was always there”* (Gray, 2003, p. 27).

In Weather-it community the moderator roles blur into each other. The PhD researcher as moderator was critical in coordinating the online community of Citizen Inquiry. She facilitated the creation of the community, provided technical and learning support, brought weather experts and non-experts closer, and sustained participation in the community. The following sections describe some of the steps the moderator took for facilitating the creation of the community.

5.5.2 Get Started Instructions

Once the participants were registered through the consent form as members of the Weather-it community, they were sent a welcome email with ‘get started’ steps. The members were welcomed by name to the community, and then they were given some steps as to how to join the nQuire-it platform. The steps included instructions and links on how to sign-up with the platform, introduce themselves to the other members of the community and learn more about the purpose and the different types of missions available on the platform. Additionally, they were instructed

on how to download the Sense-it App, join the Facebook page for daily updates and take part in the existing missions.

► Get started	Question 8/1/15 10:57 AM by Maria	3	4
► Create a mission	Help! 21/11/14 12:40 PM by Maria	5	8
► Profiles	Profile Visibility 27/11/14 5:17 PM by Maria	3	3

Figure 50: nQuire-it forum – instructions

The attached links in the instructions were forum pages within the nQuire-it platform. The information was divided into threads such as ‘get started’, ‘create a mission’ and ‘profiles’ (Figure 50). Get started topics had information about the nQuire-it missions and philosophy, and how a newcomer can join the community and become a member. Create a mission had topics with detailed guidance on how to create missions of each type (Sense-it, Spot-it, Win-it). Finally, in the profiles thread there was information for the privacy settings and visibility of the profile, as well as instructions on how to connect an nQuire-it account with a Facebook, Twitter and Google one.

5.5.3 Awards

Awards and prizes in relation to the tasks of the project were selected to be given to the participants with the best performance as a motive for increasing their participation and interest in the community:

- Monthly prizes for the top contributor – the member with the most responses
- Monthly prizes for the best photographer – the owner of the most liked picture
- Prizes for the Win-it most voted responses
- Final top contributor
- Final top sharer

The awards included £20 Amazon coupons, books related to the topic of Win-it questions, and weather stations. The prizes for Win-it missions created by members were agreed in collaboration

with the moderator. The winners were announced in the mailing list and also publicly on the nQuire-it platform and Facebook page (Figure 51).



Figure 51: Weather-it prizes announcement

5.5.4 Notifications

'Notifications' was one of the community requirements which were not implemented in the nQuire-it platform. As it was considered to be one of the essential requirements and it was questioned whether it could have an impact on the level of participation, manual notifications were initiated by the moderator at the start of the 7th week. The goal of this experiment was the comparison and assessment of the potential impact of notifications on the participation, which was explored through Social Network Analysis (Section 3.6.4.1).

The manual notifications technique follows the Wizard of Oz paradigm, by which people interact with a system that they believe to be autonomous (Hanington & Martin, 2012). However, the system is actually operated by a human being; the person behind the system is the 'wizard'. Thus, Weather-it members were sent notifications by the moderator through the official nQuire-it email thinking that it is an automated notifying email. A drawback of this technique applied to this project was the need for continuous monitoring of the platform by the moderator.

For the notifications, seven email templates (Appendix Q) were generated according to the type of notification and the role of the recipient (Table 18):

Table 18: Notification email templates

Mission post	Mission owner (immediately)
Post comment	Post owner (immediately)
	Contributor (immediately)
Mission comment	Mission owner (immediately)
	Contributor (twice a week)
Forum post	Mission owner (immediately)
	Contributor (twice a week)

5.5.5 Communication


Kraut and Resnick (2011) in their research identify factors that support and reinforce the participation and contribution of the members in the community. These factors mainly concern notifying the members about new activities and the need to contribute, encouraging them to contribute, setting goals, providing feedback, promoting existing contributions and publishing participation levels.

During this project, some actions were designed to keep the members engaged in the community. These included excerpts from the get started steps and the email notification, the creation of forum topics with updates and announcements (e.g. Figure 52), a mailing list with the new activities (Weather-it weekly updates), and Weather-it Facebook group with daily posts which aimed to remind the members to visit the community again (Figure 53). The announcements were in both written and visual image versions.

Maria

28/1/15 1:26 PM

0 0 !



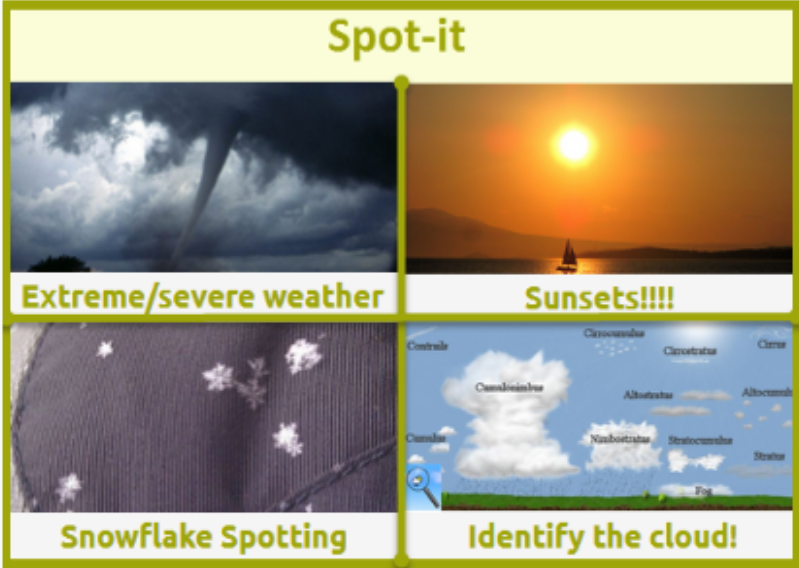
- A new **Win-it mission** has been released! **Deserts**: "Why are deserts hot during the day and cold at night? And why aren't they found at the equator?". The best idea wins a £20 amazon coupon. Submission deadline: 20/2/2015
- The deadline for **voting for your favourite answer** of the **Rain duration** mission is **Friday 30th of January at 12:00 (GMT)**. The prize for the winner is "Introducing Meteorology: A Guide to Weather" by Jon Shonk.
- The prizes for the **Top contributor, Best Photographer and Rain duration winner** will be announced on 30th January in the afternoon.
- You can upload your pictures to a Spot-it mission a) **Sunsets!!!!**, b) **Identify the cloud!** and c) **Snowflake Spotting** and **claim the prize** for the best photographer for January.
- **Vote until tomorrow** night your favourite pictures!
- If you have an android phone, download **sense-it app** and check whether you have the **pressure sensor** on it. **Air pressure and rainfall** mission is waiting for your readings J. Instructions here: <http://www.nquire-it.org/#/project/1868051/details>
- If you are an **expert**, please help us! The missions and the non-experts are waiting for your advice.
- If you have any idea for a **new mission**, please ask for my help! :D
- Finally, if you have registered with a username other than the one you had given me, could you please let me know? (e.g. who is wanstead_meteo?). It is really important for me to consider that username as one of my participants.


Figure 52: Forum – updates and announcements

Timeline Photos

Back to Album · My Photos

Previous · Next







Weather-it

Sunday Spot-it! Share with us your Sunday clouds, snowflakes and sunsets (hopefully not any severe weather incidents!) and have a great Sunday!!! 😊

Like · Comment · Share · Edit · 15 February · Edited


 Paula Chalkias, Tina Papathanasiou, Thaddeus and 7 others like this.



Write a comment...

Album: Timeline Photos

Published by Maria Aristeidou [?]

Shared with: Public

Boost Post

Tag this Photo
 Add location
 Change date

Figure 53: Weather-it Facebook group updates and announcements

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Moreover, in some cases personalised tutorials (videos and step-by-step instructions) were generated for members who had further questions. For instance, a video-tutorial demonstrating easy steps on how to upload a picture to a Spot-it mission was produced.

Finally, personal contact (not in the form of automated email) with inactive people was sought, in case the member faced problems with their participation. Therefore, the moderator was contacting the members in case they had registered for the project but did not join the community or they did not visit the platform for a long time.

These activities aimed to keep the community going by enhancing the commitment to the community (Butler & Sproull, 2002).

5.6 Summary

This chapter has described the three steps for designing the Weather-it community:

Community pre-birth preparations: This comprises the description of the software used for the project, the community requirements and features, setting up exemplar investigations and testing the tools used for the investigations.

Core group: Once the preparations were complete, and participants were invited to join the community, a core group was also formed to give life to the community and welcome the new members.

Engaging the members: Beyond the platform features that aim to make the community more appealing and the continuous recruitment of members to the community, some other techniques were employed for sustaining participation. Those mainly included get started instructions once the members register with Weather-it, tangible prizes for particular contributions, notifications to members who received feedback on their posts, and informing about the updates and needs of the community through a mailing list and the Weather-it Facebook group.

The next chapter describes the community progress and provides information about the members' engagement, the weather inquiries and the interaction of members with the software.

Chapter 6: Design Study 2 – Weather-it

Results

6.1 Introduction

This chapter presents the results and findings from the Weather-it design study. The chapter starts with an overview of the data collected and missions produced by the Weather-it members. The overview is followed by sections that examine the online community aspects (recruitment, motivation, sustainability, evolution, identity) the level and type of engagement, the investigations (participation in inquiries, inquiry patterns, vocabulary, etc.) and the feedback on the nQuire toolkit (nQuire-it platform and Sense-it Android app). In some of the descriptions, the researcher is referred to as ‘moderator’.

6.2 Overview

The following table (Table 19) shows the participation of Weather-it members (moderators included) over 14 weeks in relation to the registrations to the project, the missions, the memberships, the mission data, the mission and data comments, and the forum posts.

Table 19: Participation by Weather-it members

Weather-it Registrations	Missions	Mission Memberships	Mission Data	Comments	Forum Posts
101	24	206	422	441	188

Although the total number of missions that Weather-it members participated in is 24, the missions produced within the Weather-it project were 13. Thus, members also contributed to

missions on other topics on the nQuire-it platform, including missions related to noise maps, inquiries around bees, etc. (Section 6.5.1). Seven out of 13 Weather-it missions were created by members other than the moderators, Maria and Mike. In the previous chapter (Section 5.3.3), the settings of the exemplar missions ‘Record the sunlight’, ‘Identify the Cloud’ and ‘Earth Vs Mars’ were described. The following list (Table 20) describes briefly the other ten Weather-it missions:

Table 20: Overview of Weather-it missions

Mission	Description
Air pressure and rainfall	<p><i>“Does it rain when the pressure is low?”</i></p> <p>Sense-it mission created by member Shamal to investigate whether air pressure and rainfall are related. The mission makes use of the pressure sensor or barometer. Information about the rainfall is added to the title for each data item.</p>
Extreme/severe weather	<p><i>“Spot extreme/severe weather events or their results and upload a picture here. Let's discuss about it!”</i></p> <p>Spot-it mission created by member Stratus in order to collect and share images of extreme/severe weather with other members and discuss them and the disaster they cause.</p>
Snowflake spotting	<p><i>“Counting spotted snowflake types”</i></p> <p>Spot-it mission created by member Ostria to investigate with other members the types of snowflake in different temperatures. Snowflake pictures and temperatures were collected.</p>

Sunsets	<p><i>"All of us have seen beautiful sunsets! But how many know how these sunsets' colours are created? Upload a picture of a sunset and give your explanation!"</i></p> <p>Spot-it mission by Typhoon to investigate and discuss the factors that affect the colour of a sunset.</p>
Climate change	<p><i>"Take it for granted that there is climate change, can you summarize the things that cause it?"</i></p> <p>Win-it mission by Cumulus in order to collect ideas and spark a discussion around climate change.</p>
Rain duration	<p><i>"Which factors determine the duration of rain?"</i></p> <p>Win-it mission by Norte to collect ideas about what determines the duration of any type of rain at one specific location and discuss these ideas with other members.</p>
Climate zones	<p><i>"What affects the climate zones and what are their characteristics?"</i></p> <p>Win-it mission by member Sharki in order to learn more about climate zones, such as what defines each climate zone and what are differences between them.</p>
Deserts	<p><i>"Why are deserts hot during the day and cold at night? And why aren't they found at the equator?"</i></p> <p>Win-it mission added by Maria (moderator), set by an expert in planetary atmosphere modelling. This mission challenged members to do some research on the Earth's climate and especially the climate close to the equator.</p>

Frost	<p><i>“Why do you not get frost so often after a cloudy night compared to a clear night?”</i></p> <p>Win-it mission by Maria (moderator) set by an expert in planetary atmosphere modelling. This mission challenged members to do some research related to types of frost and when they occur.</p>
Why are there two tides	<p><i>“Why are there two tides a day, of approximately equal heights?”</i></p> <p>Win-it mission by Mike (moderator) investigating the reason there are two tides a day on Earth, and why these are of approximately equal heights.</p>

Log data showed that 58 Weather-it members joined at least one mission. Therefore these 58 active members in Weather-it joined a minimum of 1 mission and a maximum of 22 missions, with an average of four missions (mean=4.21) and a large standard deviation(SD=4.21) as the number of members joining a single mission was 16 while for joining 22 missions was one.

6.3 Community

Addressing the research questions involves the creation of an online community capable of hosting scientific inquiries and discussions. In the previous chapter (Chapter 5) the preparation of the community design was described, focusing on aspects such as the recruitment and the engagement to the Weather-it community. This section presents the outcome of the preparation, based mainly on the questionnaire responses, log files and community observation.

6.3.1 Recruitment

Interestingly, word-of-mouth through friends and colleagues has been found to be the most important factor in attracting members to the community (Figure 54). The questionnaire results show that 43% of the members invited other people to join the community. Circulating the advertisement around social networks (Facebook and Twitter) and mailing lists (NCCPE, ICHM, etc.) were in the second and the third place respectively in the recruitment of participants.

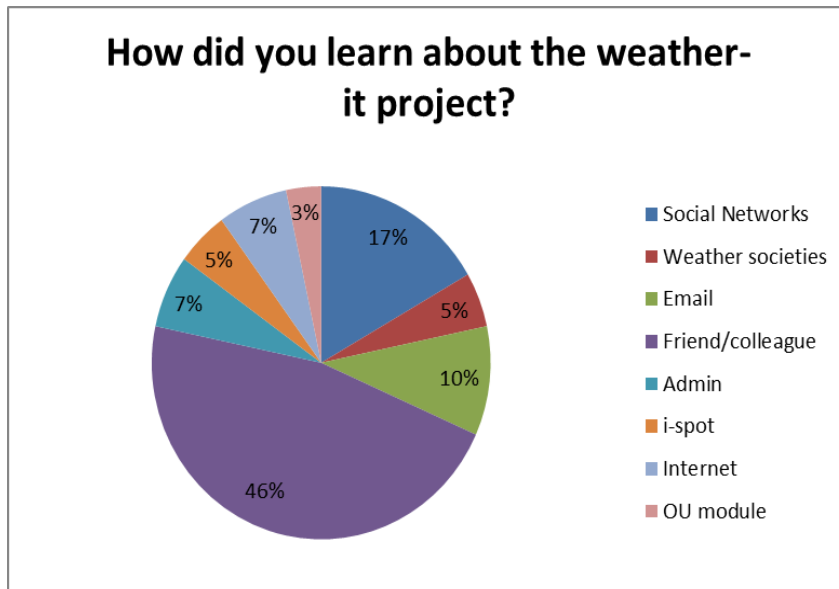


Figure 54: Weather-it recruitment

The results indicated browsing the internet as a source of recruitment. One of the members also added in her response that she came across nQuire-it when searching for the word “cloud”. Of equal importance is the recruitment by the moderator of the community, mostly of the experts. Other results include weather societies (e.g. MetOffice, TORRO, etc.), the iSpot citizen science project and finally an Open University module related to Weather.

6.3.2 Motivation to initiate participation

Most respondents gave more than one reason for joining the community (Figure 55). One of the main motivations for joining the community was interest in weather, the topic of the project, followed by friends who have already joined the community. Some members were also attracted to join because of the Weather-it community and their interest in the technology used for the investigations.

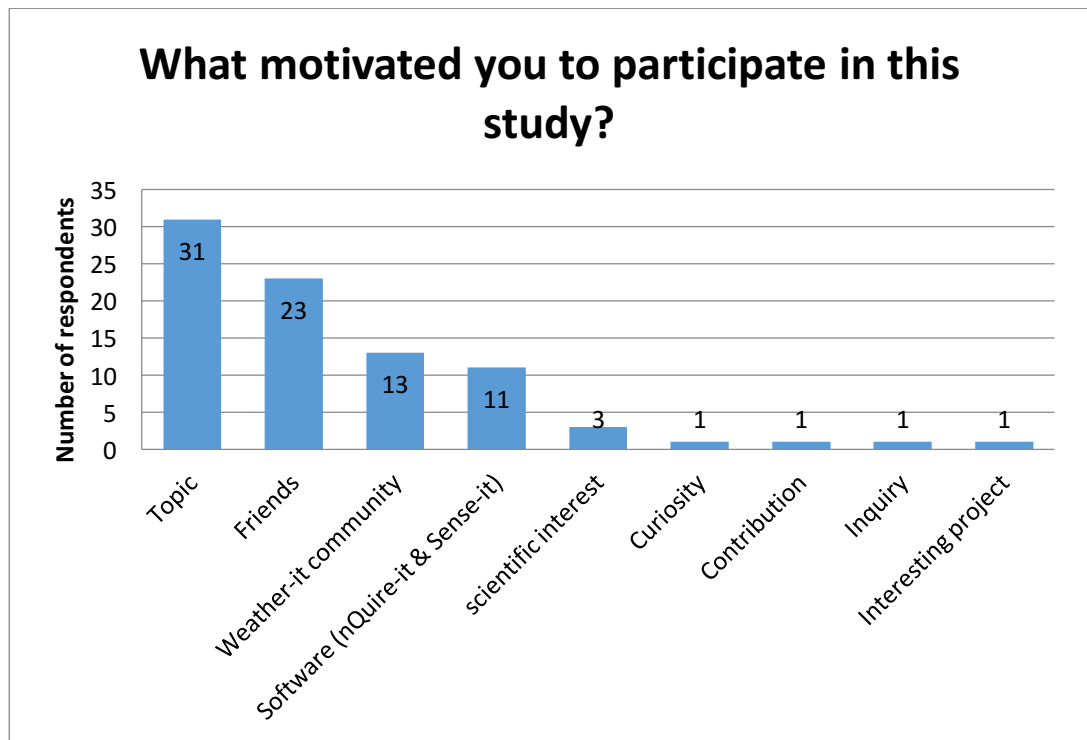


Figure 55: Motivations for joining Weather-it

A smaller number of members are motivated by their interest in science (and citizen science) while some others joined the community out of curiosity. Desire for contribution was also mentioned by one member as well as interest in inquiry and the project.

6.3.3 Participants and level of expertise

The majority of the respondents (62%) when asked about their experience of Weather, declared themselves as beginners on the topic, 25% of the participants stated that they have intermediate knowledge on weather, and 13% described themselves as weather experts.

Table 21: Weather-it – level of expertise

Expert	
Meteorologist	BSc in Meteorology
Meteorology Professor	Weather association member
PhD student	
Intermediate	
In related job	Racing sailor
Owner of weather station	Familiar with weather forecasts
BSc student in Meteorology	
Beginner	
Sailor/photographer	Country of accommodation (with unpredictable weather)
Interested in strange phenomena/sky colours/clouds	Curious/want to learn
Weather books	Weather data collection and monitoring
They hold Physics A' level	

Table 21 shows how the members justify their level of expertise. The experts are weather professionals, junior or senior academics and members of weather associations. Members that consider themselves as intermediates have a job (agronomist) or hobby (racing sailor) that requires weather knowledge, their own weather stations, or they study meteorology (formally and informally). Weather beginners may also have a hobby that combines weather (sailing/photography), study/studied weather or want to learn more about it. Some beginners are interested in particular weather phenomena or in a country's weather. Moreover, a beginner is interested in weather data collection and monitoring. Finally there were some members that have no experience of weather at all but they joined to learn about it.

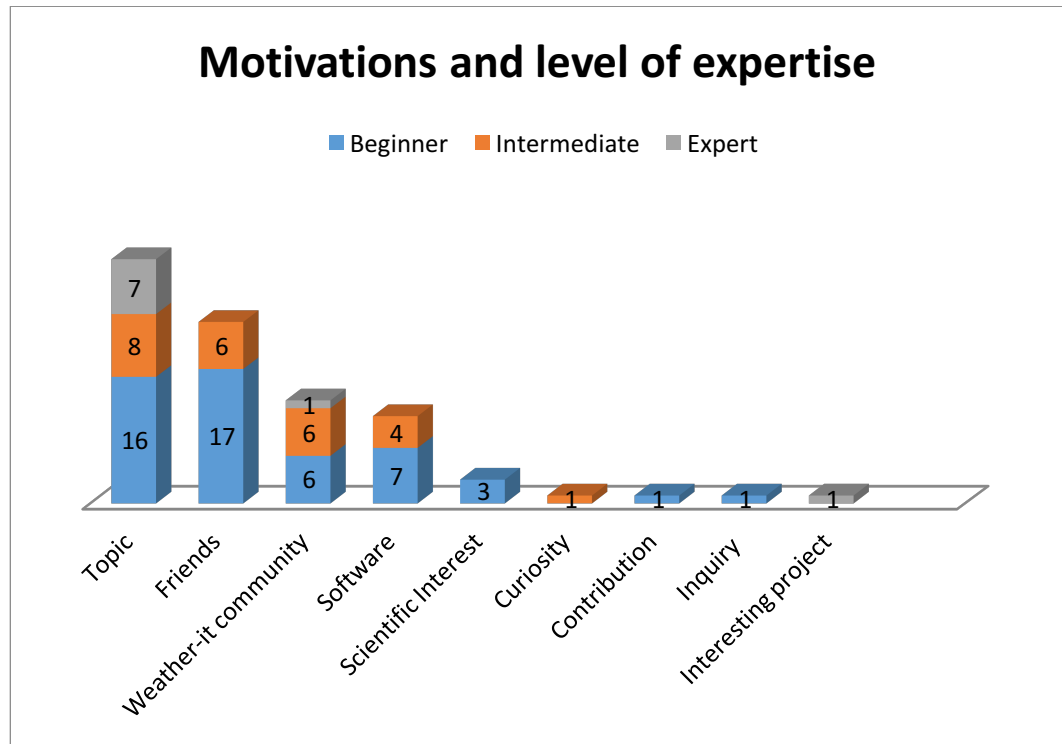


Figure 56: Motivations and level of expertise

When comparing the motivations between expert, intermediate and beginner members (Figure 56), it looks like experts were more interested in the topic whereas intermediates and beginners had more reasons to join the community beyond the topic, such as their friends who also joined the community. A reason for being motivated by friends and community comes from a beginner who has created a mission: *“We all exchanged opinions and I liked that more than searching alone”* (Typhoon).

6.3.4 Interactions overview

Visualising the community, it is easy to identify the popular and the peripheral members of Weather-it. For the visualisation, social network graphs were generated in order to conceptualise the members as nodes and their interactions as a link between the nodes. The data and software used for the creation of the graphs is described in Chapter 3 (Section 3.6.4.1). The participants who registered for Weather-it but did not register with the nQuire-it platform (23) are excluded from the SNA (see Section 3.6.4.1). The data from 78 members were then imported into Gephi in a spreadsheet and the generated network graph shows who-contributed-to-whom. The graph in

Figure 57 shows that one of the Weather-it moderators, Maria, is notably the most important member in the community.

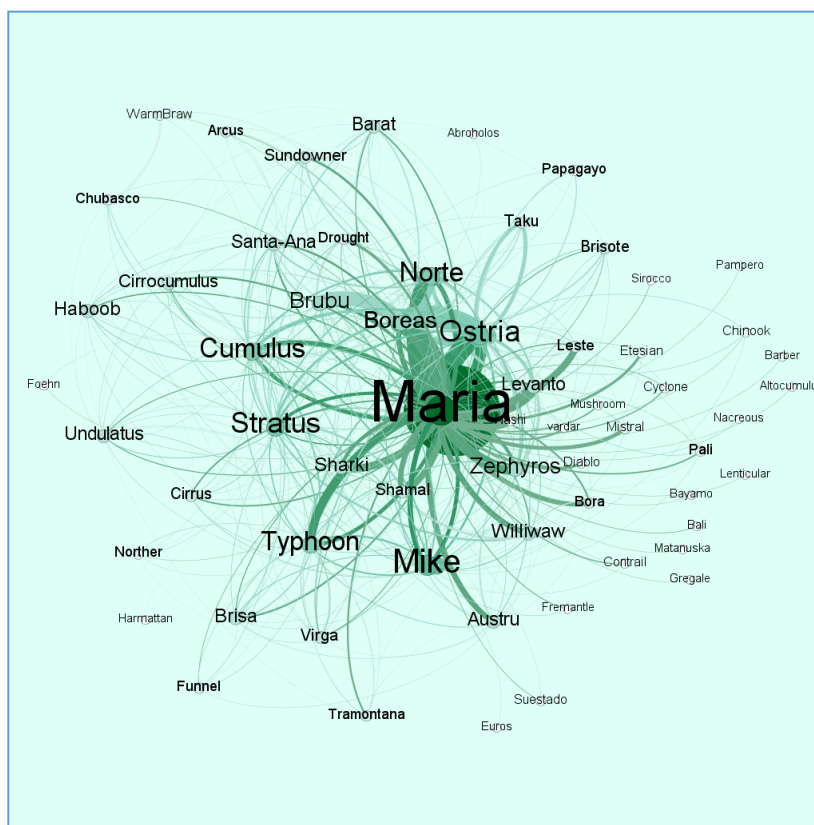


Figure 57: Visualization of the whole network of who-contributed-to-whom in Weather-it

Besides Maria and the second moderator, Mike, some other members (Ostris, Stratus, Cumulus, Norte, Typhoon, Boreas and Brubu) also seem to be high in the degree of centrality ranking and thus ‘where the action is’ (Wasserman & Faust, 1994). The rest of members have about the same level of importance overall at a lower degree of centrality, and finally there are thirteen members having a single tie – and the least importance.

In the betweenness centrality and the weighted-in degree social analysis metrics (Section 3.6.4.1) Ostris seems to come to the first place and becomes the most central member in the community and the member with the most received contributions. However, the results of the weighted-out degree helped in calculating the most active person of the community, indicating this to be Boreas. The eight members with the most received and given contributions (weighted in and out degree), who are also bolder in Figure 57 are shown in the Table 22. The weighted degree is

equivalent to the sum of number of edges for a member multiplied by the weight of each edge (how many contributions from or towards other members).

Table 22: Members with greatest weighted degree values in Weather-it

Member	Weighted degree
Ostria (expert)	273
Boreas (beginner)	251
Norte (expert)	147
Stratus (intermediate)	112
Brubu (beginner)	101
Cumulus (beginner)	101
Typhoon (beginner)	92
Zephyros (beginner)	87

From the log data it is shown that Ostria had created a Spot-it mission ‘Snowflake spotting’ and she maintained it, receiving many data contributions and providing feedback to her participants. Similarly, Typhoon had created a Spot-it mission in relation to ‘Sunsets’. Boreas tended to post data (pictures) to both Ostria’s mission and to ‘Identify the cloud’ mission, created by a moderator. Brubu was a fan of Boreas’ pictures and voted for almost all of them. Stratus, Cumulus and Zephyros were adding data and comments to all of the missions. Finally, Norte had created and maintained a Win-it mission ‘Rainfall duration’, and at the same time he commented on almost all of Boreas’ pictures. Whereas the most active participants create missions, contribute with data, comments and even votes, nine out of ten members with the smallest weighted degree value had joined a mission each, but had not contributed any further to it. The tenth member created a forum topic upon joining.

6.3.5 Community Evolution

As in Section 6.3.4, data from the 78 registered members were used to generate the community evolution graphs. The separation of the community in stages based on the data trends as described in Section 3.6.4.1 indicated that the community evolution followed a non-linear community life-cycle (Young, 2013) encountering the stages, suggested by Preece (2000), of early-life, death, and finally maturity. The stage of early-life represents the first four weeks (Weeks 1-4), with 45 nodes and 142 edges, followed by the decline of the community for the next three weeks (end of 7th week), with 52 nodes and 168 edges. In the third stage (Weeks 8-11) there is increased activity, with a total of 68 nodes and 255 ties, which leads to the final stage (Weeks 12-14) where the community matures and becomes more sustainable. The final number for the Weather-it community is 78 nodes and 420 ties.

In the first stage, the community rapidly expands due to the persistent advertisement, and it takes a first shape. The members start to interact with each other through the missions and the forum. An important factor in building ties between the members is the initial core group, which along with the moderator of the community, creates the initial missions and forum topics, so that the first participants will not find an empty place. Members of the core group also encourage the new posters by responding to their comments and commenting on their posts. Moreover, daily updates can be found on the Facebook page of the community.

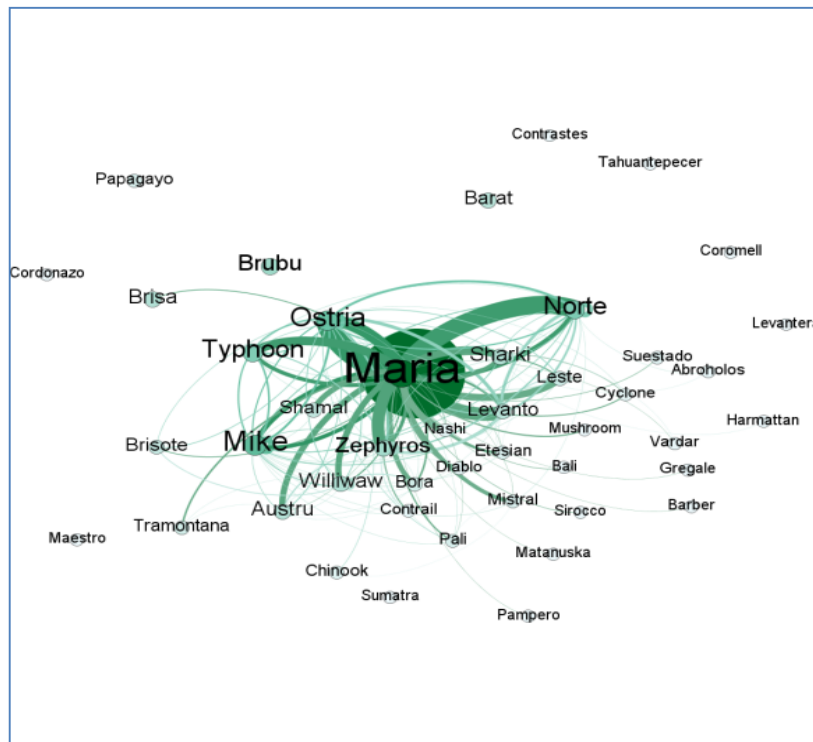


Figure 58: Weather-it network graph – end of 4th week (21/12) (45 nodes - 142 ties)

The graph in Figure 58 represents the Weather-it members and their ties according to their contributions to other members, at the end of 4th week. The 45 members of the community, including the moderator, Maria, who is the central node, had 142 interactions of any nature. The core group members had created three new missions and that increased the number of the interactions. Although the community was rapidly expanding in members, 8 out of 45 members seem not to have any interaction with others.

In the second stage (Weeks 5-7), the community is rather unchanging regarding both the members and their interactions. Possible explanations for this stasis are a) the Christmas break, which took the members away from their computers and to holidays, b) members linked to a particular mission that finished at the end of the 4th week: *“The mission I applied for (sun recording) ended”* (Nashi). c) members who felt that they had contributed enough: *“I joined a few of the missions and submitted some data and after a while I felt there wasn't much more I could do.”* (Bora) and d) the absence of notifications by that point: *“I did not communicate much with the participants, in the beginning because I was not receiving notifications about my posts, in case someone has answered, and then I lost interest”* (Austru).

The graph in Figure 59 represents the members and their interactions by the end of the 7th week. The community has 7 new members and 26 interactions within three weeks. Moreover, the eight members who had no interactions with other people in the community in the first stage, remain unconnected in stage two as well. Finally, one more member (Boreas) has obtained a central role in the community and become part of the core group.

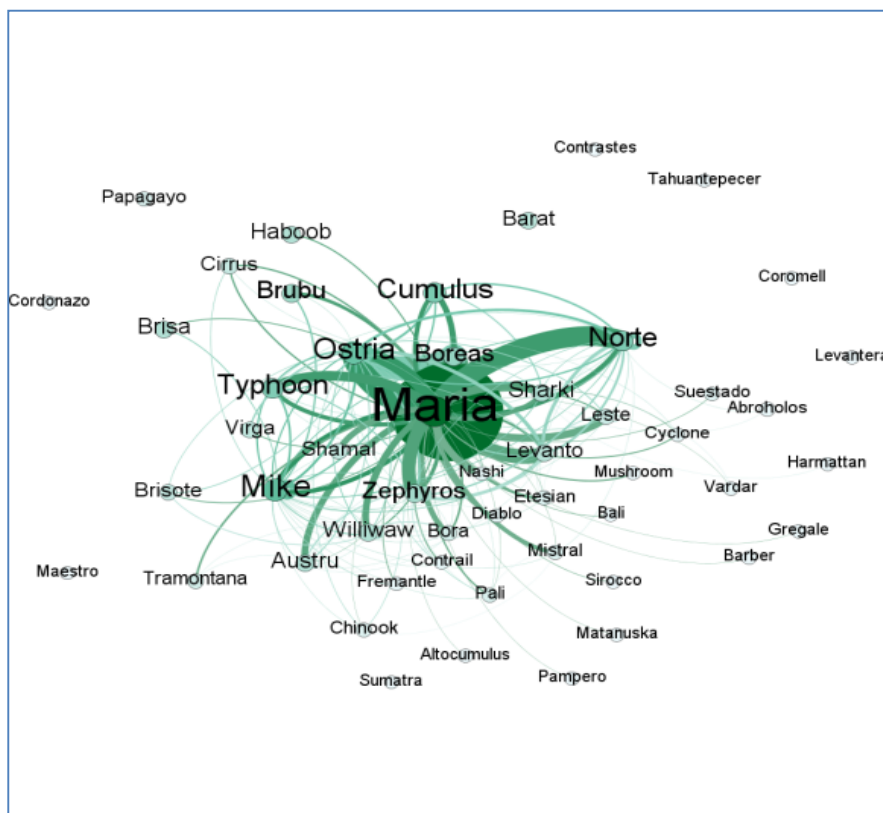


Figure 59: Weather-it network graph – end of 7th week (11/1) (52 nodes - 168 ties)

During the third stage, the community starts evolving again. The moderator sets up a manual notification system that informs the members when they have posts on their missions, and comments on their posts and forum posts. Alongside the notification system, a mailing list with weekly Weather-it updates is set, notifying the members for the community news and inviting them to contribute by adding posts or their missions. The update messages are also posted to the Facebook page and a new wave of advertisements is released and people share the community invitation with groups that may be of their interest. Finally, people who have signed up through the consent form but did not register with the nQuire-it are sent e-mail reminders.

winning the prizes and two of them are even giving negative votes to their adversaries (Section 6.4.5).

Figure 61 shows the final version of the community, at the end of the 14th week. The community has 78 members and 420 interactions, and thus a further ten members and 165 interactions within 3 weeks. There are still 15 unconnected nodes of whom four are members who joined the platform at this stage. Of those 15 unconnected members, only three completed the questionnaire. The reasons they gave for not being active are being a new member (Mammatus), lack of time (Sumatra) and bad timing (Tahuantepecer).

A video version of the community evolution can be found at:

<https://www.youtube.com/watch?v=kVzl378hvj0>

6.3.6 Sustainability

This section focuses on the number of the total active members (new and returning) every week as well as the number of contributions.

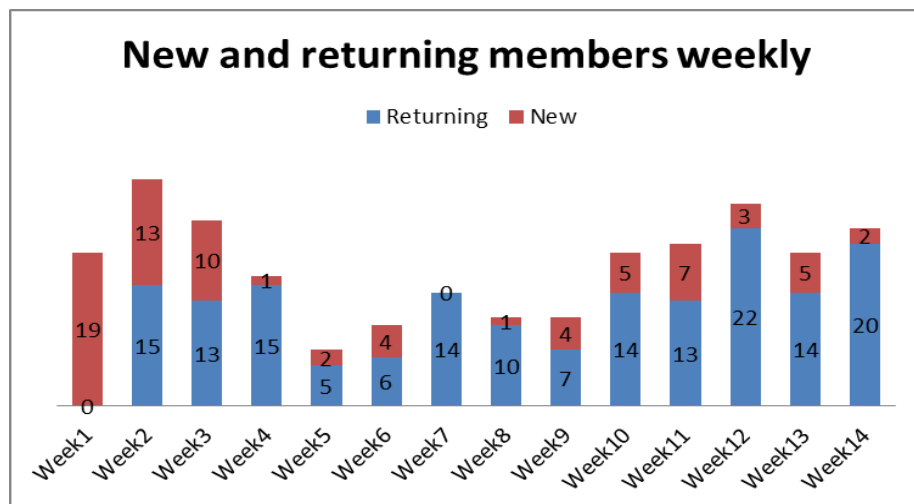


Figure 62: New and returning members weekly

Figure 62 shows the number of new and returning members weekly. Week 1 starts with the core group, followed by Week 2 and Week 3 when the advertisements are released. Week 4 faces a decline, particularly of the new members – one reason being the Christmas break. Then Week 7 shows an increase with the start of the notifications and weekly updates. Week 10 to Week 14

show a pattern that remains stable with small changes based on whether there are interesting activities for the returning participants or somebody shared the community with a new member.

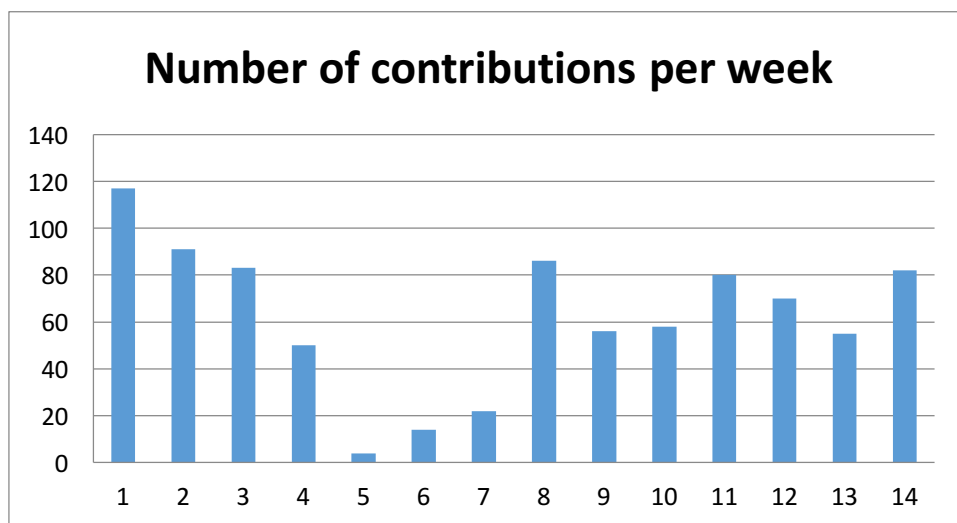


Figure 63: Number of contributions weekly

Figure 63 shows the weekly activity of the community. The contributions used for this graph include the creation of missions, forum threads, data to missions, forum posts, comments to missions or posts. The activity seems to be high in the Week 1 and then gradually decreases, reaching the bottom by Week 5, where the active members were at a minimum. Then, it increases in Week 7 with the notification establishment and takes off reaching a top point in Week 8 when two missions were released. Then, as the notifications remain stable, the level of activity fluctuates slightly according mostly to the creation of missions and posts.

6.3.7 Community Identity

Beyond the evolution and sustainability of the community, an interesting aspect is whether the members themselves feel part of this community. In the survey question (n=53), most of the respondents (68%) said that they feel like a part of the community. The participants who gave a negative answer (32%) were then categorised into three groups according to their level of participation in the community. Table 23 shows these groups, with proportion representation, and the reasons for not feeling members of the community in every group.

Table 23: Members who do not feel like a part of the community

Group	Sample
Non-registered participants (6%)	<i>"I never did anything on the site. I think it's a great idea, but the timing was bad for me."</i> (Squamish)
Participants with a few interactions (47%)	<i>"I didn't take the time to get involved."</i> (Nacreous) <i>"I wasn't very active. Mostly observing."</i> (Matanuska) <i>"I didn't really start using the website properly and so my lack of community engagement did not come from being made to feel unwelcome"</i> (Gregale) <i>"Because I felt not like a forum. It was a little bit impersonal. No participation in the extent I wanted."</i> (Fremantle)
Participants with many interactions (47%)	<i>"I did not communicate as much with the other participants."</i> (Austru) <i>"Not really because I have registered recently and I haven't spent much time on it."</i> (Funnel) <i>"Some of the other members seemed to be fairly young and I'm not!"</i> (Santa-Ana) <i>"I visit the page rarely"</i> (Brubu) <i>"I wasn't active enough nor had the time to feel like one of the community, and I believe being member of a new strange (strange in the meaning of unfamiliar) community needs some sort of communication, like face to face conversation, skype call, voice call..."</i> (Mistral)

Therefore, the reasons for not feeling a member of the community are related to the lack of time, visits, involvement, participation and notifications, but also to the perceptions of the members on the proper type of communication, the age match and the membership status. It is somehow

contradictory that a large percentage of the members who did not feel as part of the community were people who had high levels of activity on the platform.

The chi-square test indicates that there is an association between the active members (at the point of the survey) and whether they feel like a part of the community ($\chi^2 = 5.001$, $p < 0.05$, $n = 53$). This finding reflects the fact that when members feel like a part of the community, about 78% remain active and 22% are not, whereas when they do not feel like a part of the community, 53% abandon it.

6.3.8 Summary

The word-of-mouth recruitment of Weather-it members seems to be the most effective means of inviting people. Indirect recruitment through mailing lists and social networks was effective for attracting people who had no connections with the community, and thus had little prior knowledge of the community.

The Weather-it community accommodated members of all types of weather expertise (experts, intermediates and beginners/amateurs) with the majority being beginners/amateurs. Expert members were more interested in the topic whereas intermediates and beginners joined for additional reasons such as their friends who had also joined the community.

Weather-it members ranked the specific topic of the project (weather) as their first reason (personal interest and learning) for participating. Contributing to science and scientific interest ranked last, after the social-related reasons (friends and weather-it community), and the interest in the software. As expected, “Goals of the project” was not a part of the reasons that led them to join the community, as Weather-it had no specific goals linked to a single research project.

This preliminary analysis of Weather-it community has been made with the social network analysis method and helped identify the structure of the community and the interactions between the members and the missions. The results indicated the central and peripheral

members of the community and helped in planning further investigations on engagement (Section 6.3.4).

Overall, it appears that the evolution of the community depends mainly on the project communication – the advertisement, the notifications, the daily/weekly updates, and the personalised messages to the participants. Of equal importance is the behaviour of some members, such as the core group and the experts, whose contributions provide a spark of interest for other members.

The findings indicate that the sustainability of Weather-it relies upon the ongoing support of the community moderator. This supports the findings of previous research that identifies the fundamental design set in motion from the early first stage of the community development is inadequate to make the community “run itself” (Stuckey & Smith, 2004).

Although the majority of the members felt like a part of the community, an important percentage did not. Surprisingly, almost half of those are members with many contributions to the community. The reasons for not feeling a part of the community are related to a) the absence of opportunities for bond-based commitment (members closer to other members) as the community was mission-centric, b) homogeneity issues (different age), c) frequency of visits, and d) duration of participation (newcomers).

6.4 Engagement

Engagement in the community was one of the main factors investigated in the course of Weather-it creation. Several techniques were used during the preparation of the community (Section 5.3.2 and Section 5.3.3) and more interventions took place while observing the community evolution and behaviour (Section 5.5). This current section describes the participation of Weather-it members based on the level and type of engagement, followed by a self-report on the reasons that caused members to be engaged or disengaged with the community and finally reporting on the impact of awards on participation. The engagement of Weather-it was explored through

engagement metrics, clustering into engagement profiles and thematic analysis of self-reports on engagement.

6.4.1 Level of Engagement

Table 24 shows the descriptive statistics of engagement metrics of members in Weather-it dataset in comparison to those of 'Milky Way' and 'Galaxy Zoo' projects, produced by Ponciano and Brasileiro (2015). The metrics used for this analysis are described in the Research Methods Chapter (Section 3.6.4.2). For the calculation of the engagement metrics, several data for each user were collected, such as the number of active days, the number of lurking days, the total days a user remained linked to the project and the number of days between joining and end of the project (Appendix R).

Table 24: Comparison of average engagement metrics in three projects

	Weather-it	Milky Way	Galaxy Zoo
Activity ratio	mean = 0.32, sd = 0.35	mean = 0.40, sd = 0.40	mean = 0.33, sd = 0.38
Daily devoted time	no data	mean = 0.44, sd = 0.54	mean = 0.32, sd = 0.40
Relative activity duration	mean = 0.43, sd = 0.44	mean = 0.20, sd = 0.30	mean = 0.23, sd = 0.29
Variation in periodicity	mean = 5.11, sd = 5.36	mean = 18.27, sd = 43.31	mean = 25.23, sd = 49.16
Lurking ratio	mean = 0.35, sd = 0.39	no data	no data

The results show that Weather-it members were less active during the days they were linked to the project in relation to those of Milky Way but almost as active as the volunteers in Galaxy Zoo (activity ratio). The daily duration users spent in the community was not calculated as there was no reliable information in the log data (daily devoted time). In Weather-it, members seem to be more persistent and linked to the project for longer than those of the other two projects, but with

bigger standard deviation (relative activity duration). Furthermore, Weather-it members were more constant with their visit frequency (variation in periodicity). Finally, there is no data for comparing the lurking ratio, though research showed that a small number of volunteers do a disproportionate amount of the work whilst others prefer to be observers (Curtis, 2015). The lurking ratio in Weather-it indicates that members were lurking in approximately one out of three visits.

6.4.2 Engagement Profiles

The engagement profiles of Weather-it members were created based on the clustering described in Section 3.6.4.3. First, the members with two or fewer active days composed a separate engagement profile named 'visitors'. Then the rest of the members were clustered to engagement profiles according to the individual results of the lurking ratio and the metrics proposed by Ponciano and Brasileiro (2015), with daily devoted time excluded.

The hierarchical clustering algorithm, as described in Section 3.6.4.3, indicated 2 to 6 number of clusters as the interval to be tested. The result of the clustering quality when the number of clusters ranges from 2 to 6 is shown in Figures 64 and 65. Figure 64 presents the results from the clusters' cohesion (Average Silhouette width) for each potential number of clusters, and Figure 65 demonstrates the similarities between clusters (Davies-Bouldin index). The cross validation between the two methods for determining the optimal number of clusters show that 4 is the best option. This number of groups returns an Average Silhouette statistic of 0.68 (reasonable to strong structure) (Struyf, Hubert & Rousseeuw, 1996) and Davies-Bouldin index of 0.74 (minimum inter-cluster similarities) (Davies & Bouldin, 1979).

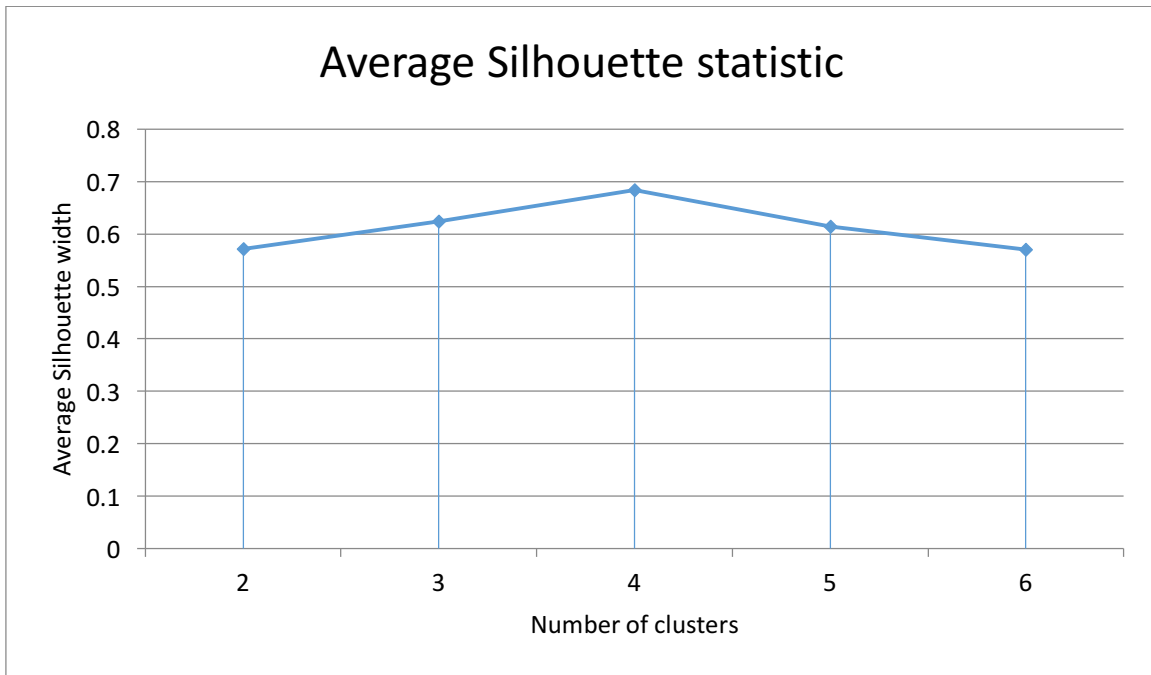


Figure 64: Average Silhouette statistic for potential number of clusters

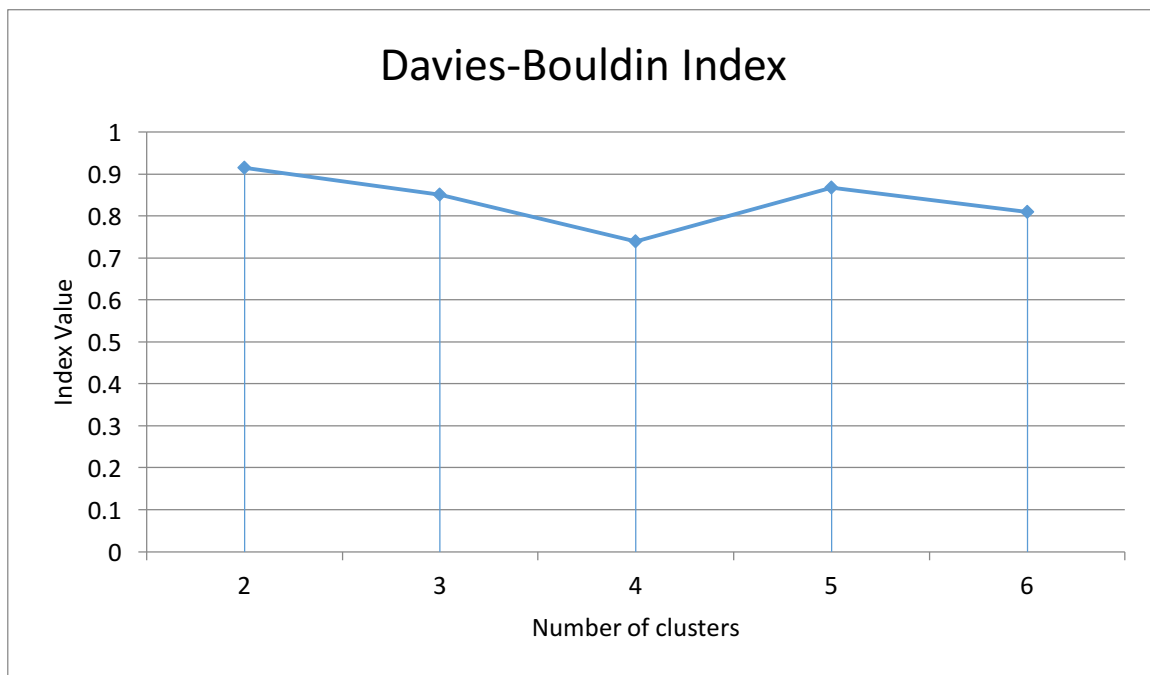


Figure 65: Davies-Bouldin index for potential number of clusters

K-means, as described in Section 3.6.4.3, was then used for the classification of the data with K=4 and the centroids that were produced by the hierarchical clustering algorithm; the four generated categories represent member engagement profiles. The name for each profile was chosen or borrowed from Ponciano and Brasileiro (2015) so that it characterises the main behaviour of a specific group of members within the Weather-it community. Figure 66 shows a comparative chart with the metrics average for each engagement category, with each bar representing one engagement metric, the horizontal axis the engagement categories and the vertical axis the scores for each metric. Table 25 (at the end of this section) summarises the main features of each profile. The members of each engagement profile can be found in Appendix S.

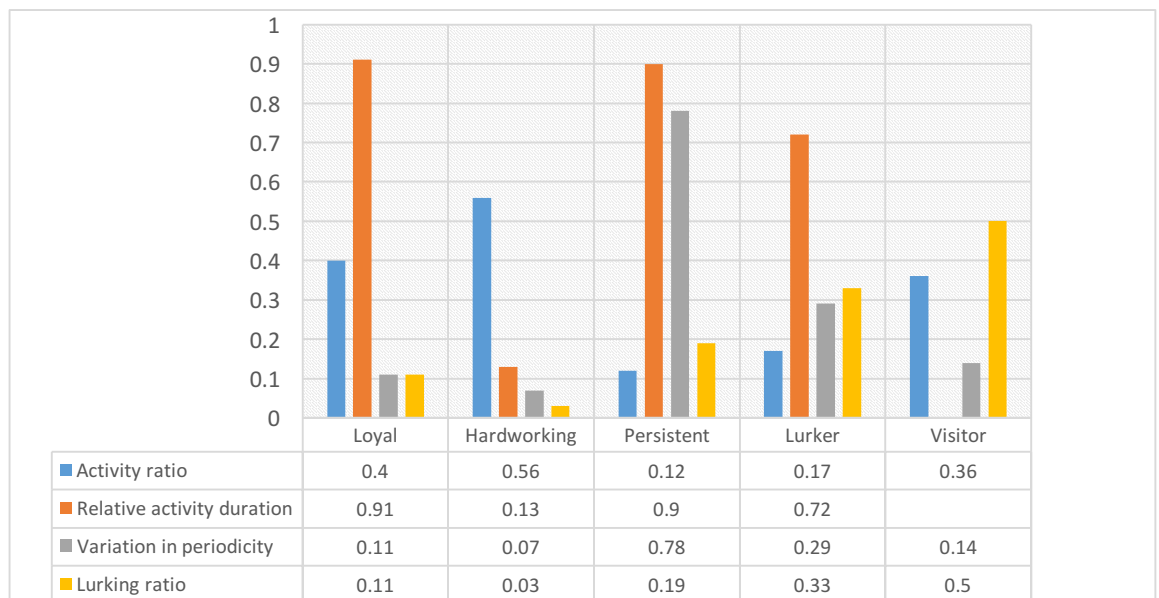


Figure 66: Weather-it engagement profiles

Loyal engagement. Members of the loyal engagement profile demonstrate the largest relative activity duration, combined with moderate activity ratio and low variation in periodicity. This means that members of this category remain linked to the project the longest with steady visiting rates, and they are active nearly half of the days they are linked to it. In addition to that, the low lurking ratio indicates the small number of days that they visit Weather-it without being active. Nine out of ten members in this category were surveyed with eight of them still being active on the data of survey; the ninth one had left the project as the mission they joined for had finished.

Respondents consisted of four beginners, four intermediate and one expert. According to the survey, the main reasons that attracted initial participation in the project are 'weather' (47%) and 'community' (20%), followed by 'software', 'friends', and 'science'. Respondents joined missions of all types, from one to eight, and contributed their data. All of them felt part of the community and eight out of nine would like to remain members. Their attitudes towards the project are mainly 'enthusiastic' (25%), 'interested' (25%) and 'active' (25%), followed by 'excited', 'inspired' and 'not bored'. Moreover, one member chose 'guilty' adding *"when I do it during work time"*. Overall, loyal members are satisfied with the project as experts *"are willing to help"* and *"explain things in a better way"*, and there is *"variety of members and topics"* and *"plethora of topics to discuss"*. Learning was also a reason for feeling satisfied, with comments: *"insight into some topics"* and *"new information"*. In relation to the community there were comments such as *"sharing is fun"*, *"the members are friendly"*. Finally, the expert in this category *"likes explaining phenomena to non-experts"*.

Hardworking engagement. Members of this category exhibit low variation in periodicity and lurking ratio. This means that they visit the platform at regular time intervals and they are nearly always active during their visits. However, this category has the largest activity ratio and the shortest relative activity duration compared to other profiles, which shows that although they are considerably active during the days they are linked to the project, they do not remain linked to it for a long time. Survey findings from four out of five hardworking members, all beginners, reveal that they joined the community at its launch and their motives for initiating participation include 'weather' (33.3%), 'software' (33.3%) and 'friends' (33.3%). In contrast to the loyal members, 'community' is not in their motives, and only half of them feel members of the community and would remain linked to it. None of the hardworking members remained linked to the project to the end. Their attitude towards the project community are mainly positive with 'interested' (25%) being first, followed by 'active' (17%), 'proud' (17%), and 'enthusiastic' (17%). Finally, a negative response was 'nervous' but the member added *"nervous if I identified a subject correctly but it's part of the excitement"*. Overall, hardworking members are satisfied with Weather-it as it is *"open*

and helpful to beginners” and “the community was discussing the missions and not just submitting data”.

Persistent engagement. This category consists of 14 members and is characterised by the largest variation in periodicity and the relative activity duration which is almost as high as in loyal members. Thus, persistent members remain linked to the project the longest but they do not visit Weather-it in a steady rate. At the same time, activity ratio is quite low indicating the small number of active days they have during the period they are linked to the project. However, lurking ratio is also low, suggesting they are active during their visiting days. All but one member of this category were active until the end of Weather-it and 14 responded to the survey. Eight of them were beginners, five intermediates and there was also one expert. ‘Friends’ (37%) is the most frequently motive for initiating participation, followed by ‘community’ (26%) and ‘weather’ (16%). Other responses include ‘software’, ‘inquiry’, and ‘curiosity’. All but three would remain members of the community. The most common attitude for participating in Weather-it is ‘interested’ (28%) followed by ‘active’ (23%) and ‘enthusiastic’ (20%). The ‘active’ response however is in contrast to the activity ratio result, which may suggest their satisfaction with the number of active days during their visits. Persistent members seem to be satisfied with *“diversity in topics and people”* and *“learning about things”*, and characterised the members as *“friendly”* and the community *“scientific but friendly and funny”* and *“certainly not boring”*. However, there was some criticism in relation to the investigation and participation aspects such as *“I would like the missions to be more informed”* and *“more participation needed”*. Moreover, the expert of this category did not understand in which way experts can be useful.

Lurking engagement. Members have comparatively high relative activity duration and low variation in periodicity, and thus they remain linked to the project for a long time and visit it at a good rate. However, the low activity ratio combined with the comparatively high lurking ratio, indicate that they are active for only a few days during their stay in the project and exhibit lurking behaviour during one third of their visiting days. Four out of the five lurkers responded to the survey, three beginners and one intermediate. ‘Weather’, ‘community’ and ‘friends’ are equally

important motives for initiating participation, followed by 'contribution'. Only two members were active until the end of the project. The two lurkers who dropped out, did not feel as a part of the community because *"some of the members seemed to be fairly young and I am not"* and *"because I felt not like a forum. It was a little bit impersonal, no participation in the extent I wanted"*. However, three of them would like to remain members in the community and the fourth one said that they *"did not understand the point of the community"*. The lurkers' attitudes towards the project are solely positive with most important being 'interested' (50%), followed by 'inspired' (25%), 'proud' and 'determined', with the obvious absence of 'active' which appears in the other categories. Members are mainly satisfied with the project as it is *"well-organised"*, and *"software bugs are fixed"*, however somebody added that it should have been *"more collaborative"* whilst another expected *"an automatic system able to process uploaded photo and then to detect the weather"* instead of a community.

Visitors. Members of this profile only contributed to the project on one or two days, or even never, and thus their variation in periodicity cannot be compared. Their second main characteristic is the short relative activity which is similar to that exhibited by hardworking members who do not stay for a long time in the project. Moreover, the activity ratio is similar to the loyal members' one and the lurking ratio higher than the lurkers. This category embraces the majority of the members (43) and as it includes many new members and diversity in results further analysis took place. Twelve visitors exhibited more active behaviour, twelve exhibited hesitant behaviour, and 17 lurking behaviour. Responses to the survey came from 23 members, 14 beginners, three intermediate and six experts.

(a) **Active visitors** joined Weather-it because they are interested in 'weather' (57%), 'software' (14%), 'community' (14%) and 'science' (14%) and during their short stay made contributions within the project. Six out of twelve members completed the survey; the respondents consist of three beginners, two intermediates and one expert. Four out of six were not active at the end of the project as they *"participate in other citizen science projects"*, *"lack of time"* and *"joined late and did not get around to participating in any of the projects"*; the remaining two are new

members. Three reported feeling like members of the community due to the “updates” or because although they are new members they *“could see themselves as active members of the community”* and four would remain in the project. ‘Attentive’ (20%) and ‘excited’ (20%) are the main attitudes towards the project with ‘curious’, ‘enthusiastic’, ‘inspired’, ‘alert’, ‘guilty’, and ‘active’ following. Furthermore, a respondent adds *“I’m excited to see other people interested in the topic but guilty for not getting involved”*. This is the only category that ‘interested’ is not in the listed attitudes. Active visitors are mainly satisfied with the project, some *“desire to spend more time”* and some others wonder what it was like for the people who joined at the beginning of the project *“I liked what I saw, I am not sure for the people who joined at the beginning and there were no missions”*. Yet, an intermediate member found the *“level of discussion lower than expected”*.

(b) **Hesitant Visitors** group consists of 17 members, of which twelve responded to the questionnaire; eight beginners, one intermediate and three experts. A main thing that differentiates this group from all the other categories is that only four out of twelve members joined because of the topic and hence it was mentioned four times (33.3%). A motive of equal importance to the topic was ‘friends’ followed by ‘software’, ‘community’ and ‘interest’. Four out of twelve left the project because they had “no time” or they found the software “complicated”; three members feel like members of the community. The main attitude of hesitant visitors towards the project was ‘interested’ (38%) followed by ‘enthusiastic’ and ‘active’. However, for the first time in this group there are a variety of negative attitudes such as ‘distressed’, ‘afraid’, ‘ashamed’, ‘scared’ and in addition *“confused with the website, yet I was interested in the topic”*. Overall when asked whether they are satisfied there were no negative comments as they found the project *“useful to read other people’s interpretations”* with satisfactory *“range and quality of responses and contribution”*. Finally, ten out of twelve hesitant visitors would like to stay linked to the project.

(c) **Observing Visitors** had more lurking days than active days during their short stay. This group consists of 14 members of which four responded to the survey. The motives for the two beginners

and two experts for initiating participation in the community were 'weather' (68%) and 'friends' (32%) and thus there was no interest in the community and the software. Two out of four are new members and these were active until the end of the project and three out of four feel like a part of the community because of the *"excellent project communication"* and *"due to the updates in the inbox"*. Moreover, a new member adds *"I could feel like a member if I had joined earlier but I think you can easily become one as the environment is friendly"*. The attitude towards the project was 64% positive and 36% negative with 'interested' (27%) being the most important, followed by equally mentioned 'inspired' (18%) and 'guilty' (18%) and then 'ashamed', 'determined', 'afraid', 'enthusiastic' and 'active'. A comment by a member is *"I'm feeling ashamed and guilty for not doing anything due to the lack of time"*. Overall, the fact that three out of four would like to stay in the project in combination with their comments indicate their satisfaction with the project: *"I was expecting a discussion forum so it is much better"*, *"I love the interactive approach to learning. It's great that people can contribute to science using technology in a fun and interactive manner"*.

Table 25: Engagement profiles – summary of main features

Engagement profile	Loyal (10)	Hardworking (5)	Persistent (14)	Lurker (5)	Visitor		
					Active (12)	Hesitant (17)	Observing (14)
Surveyed	9	4	14	4	6	12	4
Beginners	4	4	8	3	3	8	2
Intermediate	4	0	5	1	2	1	0
Experts	1	0	1	0	1	3	2
Motivations (descending order)	weather community software friends science	weather/ software/ friends	friends community weather software inquiry curiosity	weather/ community/ friends	weather software/ community/ science	weather/ friends software community interest	weather friends
Attitudes (descending order)	enthusiastic/ interested/ active excited inspired not bored guilty	interested active proud enthusiastic	interested active enthusiastic	interested inspired proud determined	attentive/ excited curious enthusiastic inspired alert guilty active	interested enthusiastic active distressed/ afraid/ ashamed/ scared/ confused	interested inspired/ guilty ashamed/ determined /afraid/ enthusiastic/ active

6.4.3 Activity

Following the clustering of engagement profiles, there was an attempt to cluster Weather-it members based on the type of the activities they were engaged in. However, the attempt was not successful as there were no clear clusters as in the engagement profiles. In other words, members

were engaging with a variety of activities. Thereby, in this section the activity in the community is not described based on activity profiles rather with examples of activity with people who primarily engaged in the particular type of activity, or had exceptional participation. The description of the activities is based on the log files and survey responses.

6.4.3.1 Mission Creation

Weather-it community allowed participants to create their own personally meaningful mission and invite other people to facilitate the investigation (e.g. Figure 67). Seven out of the 58 active members exploited the opportunity and started their investigation. Of those three were beginners, two were intermediates and two experts. None created more than one mission.

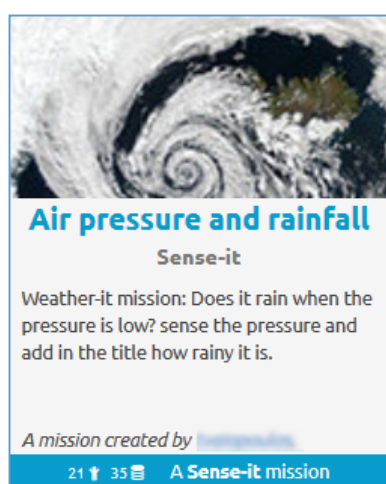


Figure 67: Mission creation by member 'Shamal'

6.4.3.2 Data creation

Weather-it members, as seen in the overview (Section 6.2), collected a total of 422 data (sensor recording, pictures and ideas). An 'extreme contributor' who distinguished himself with the enormous amount of data contributions was Boreas. Member 'Boreas' heard about Weather-it from iSpot and he was motivated to join by the topic and his scientific interest. Boreas is a beginner as he said he only knows *"a small bit such as cold front and that knots are how wind speed is measured"*. Once he registered with Weather-it, he joined two Spot-it missions, 'Identify the cloud' and 'Snowflake spotting', and started publishing pictures because as he stated in the survey *"Spot-it gives me a reason to put my digital camera to good use"* (Figure 68).

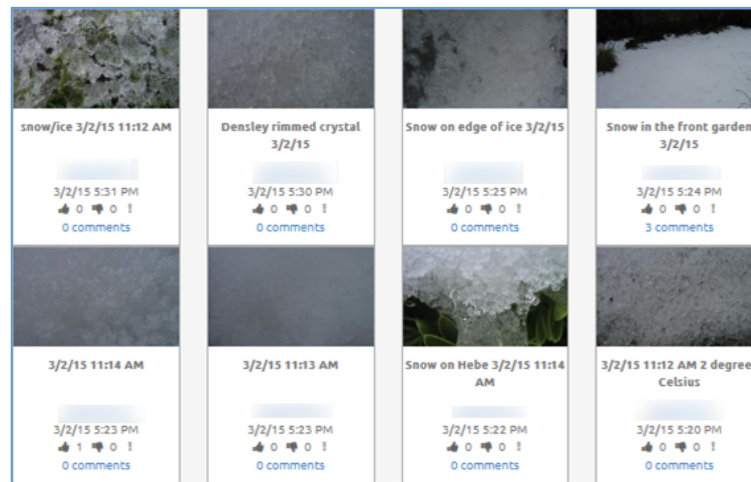


Figure 68: Member 'Boreas' uploading pictures to 'Snowflake spotting' mission (extreme contributor)

6.4.3.3 Commenting

A total of 441 comments were posted to missions and data (Section 6.2). An example is member 'Norte', who is a meteorology expert and he heard about Weather-it from a friend, member of the community. 'Norte' joined Weather-it and started being active in many ways, adding missions, forum threads, data, comments and votes. However, his main activity was providing advice to less expert participants through his comments (Figure 69) and as he stated in his survey response *"It is always helpful for me to try to explain weather processes and phenomena to non-experts"*.

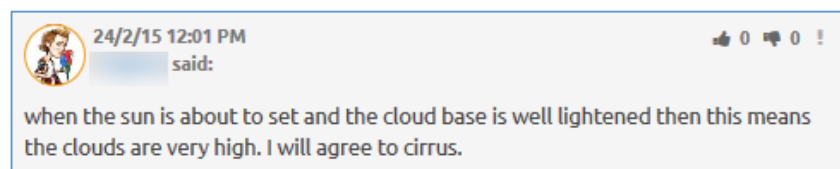


Figure 69: Member 'Norte' is providing advice on a cloud picture (commenter)

6.4.3.4 Voting

Weather-it members voted on their favourite comments and data. A member who demonstrated high activity on voting was 'Brubu' who heard about Weather-it on Facebook and joined because she liked the community. She first introduced herself on the forum topic 'Introducing myself'. She joined 17 missions but restricted her activity to voting (positively) on other members' data. She only uploaded some pictures and commented on a number of data in the last two weeks of Weather-it. Brubu in her survey responses mentioned that her English is not very good and this is

why she has not created a mission. She also added *“language selection”* in her suggestions for improving the platform. Lack of English language may be the reason for her voting behaviour.

6.4.3.5 Forum posts

Weather-it members published 188 forum posts during the project. The forum posts were relating to weather and the missions (on-topic) and everyday things (off-topic).

On topic forum posts: forum topics were used as a means for further discussion on the missions (Figure 70). For instance, ‘Bora’, an amateur member, who was interested in the ‘Record the sunlight’ and use of sensors got involved in forum discussion about it. Bora expected that *“there will be a discussion around the measurements and findings”* and she was satisfied *“to see that the community was open and helpful to beginners”*.

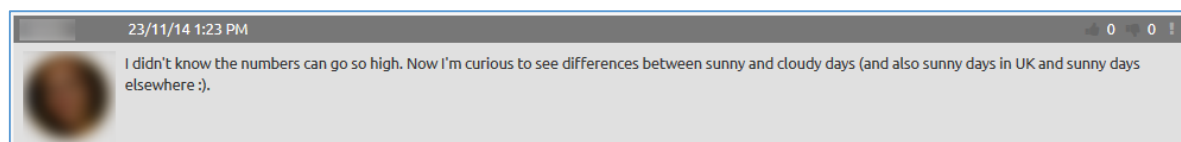


Figure 70: Member 'Bora' leaves feedback on results (on-topic forum posts)

Off topic forum posts: a few members got engaged in discussion which was not related to the topic of the project. Five different threads of diverse topics were created (chat, travelling, Christmas, photography, and socks) with a total of 39 forum posts. Off-topic discussion was a significant aspect of the community as it supported communication and enhanced bond-based commitment between the members. A forum post example is Austru's, who joined the community because of her friends who were already members. She posted in several off-topic forum threads to spark discussion with other members of the community (Figure 71). In the questionnaire she stated that Weather-it *“is a community that inspires interaction with the content (missions) and people”*. Austru's suggestions on improving the community focus on the use of notifications as she wants to be *“alarmed when somebody may answer to my posts or comments”*.

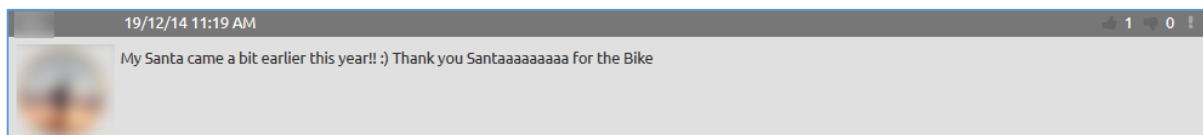


Figure 71: Member 'Austru' posting on off-topic forum threads

6.4.3.6 Browsing

Many members although they have joined missions did not proceed to any other activity and remained 'Watchers' of the community. An example is member 'Foehn'. Foehn heard about Weather-it from iSpot. He joined the project as he found the topic interesting; he had some experience of weather through his *"OU studies on environmental sciences which include meteorology and climate change"*. After viewing some pages he became a member of 'Climate Change' Win-it mission as he said *"I wanted to test my written communication skills"*. Foehn did not post any ideas/comments on the mission nor voted for his favourite one. He returned five days later to view the same mission without interacting in any other way. However Foehn was satisfied with the community: *"it exceeded my initial expectations in the range and quality of responses and contributions"*.

6.4.4 Self-report on engagement/disengagement

Beyond the clustering and the observations, members were also asked, indirectly, about the reasons they got engaged or disengaged with the community. This section provides the main engagement/disengagement themes and the members' quotes behind them.

6.4.4.1 Engagement

In the questionnaire participants were asked what they liked the most in Weather-it project. Figure 72 shows a word cloud with the 14 most popular words that appeared in their responses.



Figure 72: Word cloud – what did you like the most in Weather-it?

The word cloud suggests that main factors for one to like Weather-it were the pictures, the missions, the project idea, the topic of the project (weather), contributing, the clouds, the community, etc. More details from the participants’ responses can be found in the following analysis. From the responses (n=51) four main themes have emerged (Table 26).

Table 26: Self-report on engagement

Variety	This theme includes variety in level of weather knowledge, members and countries, and variety in topics and ways of contribution.
Social Aspect	The social aspect theme involves topics such as the interaction and collaboration between the members, perspectives by other community members, the active role of the individual members and the feeling of being part of the community.
Concept	Respondents referred to the concept of the project. In particular, they mentioned the missions-driven investigations, the crowdsourcing aspect, the engagement of people with science, the prizes, the opportunity to start an investigation, the social learning aspect and the sharing/contributing aspect.
Software	Questionnaire responses included software as one of the main aspects they liked in Weather-it. More information can be found in Section 6.6 which is exclusively dedicated to the nQuire toolkit.

Variety

One of the things that Weather-it members liked was the variety in the community. Having a range of investigation types that you could engage in was seen as a positive aspect of the project as many people had a preference regarding the data collection method and inquiry activity. For instance, Undulatus was one of these members:

“That you have option for which type of mission you prefer to join” (Undulatus)

Undulatus preferred to join Win-it missions *“because it is something you can do if you study a bit about the topic”* and Spot-it *“because you can upload pictures from everywhere”*. Furthermore, when questionnaire participants (n=43) answered about which type of mission they preferred 73% had a single preference, 19% preferred two types of missions and only 8% had no specific preference.

Another reason for liking Weather-it was the variety in topics: *“There were a good variety of weather topics featured – from Weather sayings to clouds and instruments”* (Arcus).

Weather-it members were allowed not only to create their own missions but they also had access to create forum threads according to their interests. As a result, there was diversity in topics that could satisfy all the interests and engage members in different kind of discussions and inquiry levels. This diversity was also good for allowing people of any level of weather knowledge to join in:

“That people with any level of knowledge of weather could participate” (Chubasco)

The diversity of topics and variety of members led to a large range of data contribution. Member Taku liked the special characteristics that posts from different members carry: *“The photographs are all contributed by different members within the community. Everyone's work is different”* (Taku). Indeed, the content of the contributed pictures depends on the individual member's habits, interests, point of view, location, etc.

On the other hand, member Zephyros, for instance, focused more on the location and highlighted the fact that members from around the world pulled together in order to carry out a mission:

“I was new to the idea of people from all around the world collaborating and contributing with ideas or data for the same goal.” (Zephyros)

Zephyros participation was mainly focused on Sense-it and Spot-it missions. In those missions contributions were usually linked to locations.

Social Aspect

The social aspect of Weather-it was the focal point of some other references in relation to what members liked in Weather-it. As a community, Weather-it was designed to enhance the community feeling to its members. Several responses suggest that this cause was successful. For instance, what member Boreas liked was *“The sense of being a part of something”*. Furthermore, as mentioned in the ‘Community Identity’ (Section 6.3.7), 68% of the questionnaire respondents answered that they feel like a part of the community. A reason for that may be the following comment by member Brisa on what she liked in Weather-it:

“The feeling that my contribution was welcome and accepted.” (Brisa)

The welcomed contributions by all the members led to a more active role for the members:

“I liked that the participants had an active role in weather-it.” (Contrail).

Members could start the own missions, post their data and comment on other members’ contributions. This freedom of open participation led to a collection of diverse perspectives that members such as Sumatra liked in Weather-it:

“The interesting perspectives and missions from other community members.” (Sumatra)

In other responses, the quantity of contributions was sought as important, acclaiming the community about its activity rate and its communication.

“There was always something new to do and something new to learn.” (Stratus)

“There were a varied number of topics and members were regularly updated on the latest news.”

(Chubasco)

Several members also mentioned the interactions in the community as the reason they liked Weather-it. For instance, a short statement by Zephyros praises the community environment which facilitated narrower connections between the members:

“Weather-it is not impersonal and cold, like some other platforms I tried. On the contrary, it promotes user interaction and close relations.” (Zephyros)

Concept

A number of responses focused on the underlying concept behind the project. Weather-it members were informed at their registration about Citizen Inquiry being the theory that supports the Weather-it project. The following comments show that participants had a liking for this concept regardless of whether they were aware of it. For instance, member Cumulus liked *“That you could start your own mission and people would follow and help”*. Creating your own investigation according to your interests and everyday experience of science is one of the key aspects in Citizen Inquiry. Cumulus who had created a Win-it mission with other members contributing to her investigation, appreciated this opportunity and nQuire-it feature of commencing a mission.

On the other hand, people who had not created their own mission, but contributed to other members' missions, liked the fact that they were *“feeling helpful”* (Mistral). Moreover, some members considered their participation as pleasure. For instance:

“I thought the whole process of measuring and submitting my own measurements was fun.”

(Bora)

Weather-it is a community for people to join voluntarily during their free time as it constitutes an informal way to learn about science and engage with investigations. Several members recognised this opportunity and liked the possibility of learning through interacting with other members.

"It is a great opportunity to learn things while relaxing in your free time." (Norte)

"I feel that I did learn and that interacting with others is a great way of learning." (Boreas)

There was also a comment that referred to the way that investigations were conducted, in a "missions" way. Mission is the particular nQuire-it way to make the investigations sound more interesting. Member Euros liked the mission-driven investigation and the open discussion taking place in them.

"The idea of an open discussion on weather topics driven by missions." (Euros)

One Weather-it member seemed to be a citizen scientist involved in many citizen science projects. In his questionnaire response he stated that he liked citizen science projects and he seemed to consider Weather-it as one of them.

"I really enjoy citizen science and in addition to weather-it I am a part of zooniverse.org and other sites/organizations." (Boreas)

When Boreas was asked during his interview whether he noticed any differences between Weather-it and other citizen science projects, he responded *"not really, maybe Weather-it is more informal and has more interaction between people."* Therefore, 'more interaction' may be a key point for distinguishing Citizen Inquiry projects from others. There was not any follow-up question asking about what "informal" means to him, but it might imply that the investigations were driven by non-scientists.

Another member found a different way to describe what she liked in Weather-it:

“Very enjoyable and an excellent way of getting people into scientific investigations without making it too difficult.” (Brisa)

Her idea regarding Weather-it community focused on the citizen participation aspect that she thought was very *“enjoyable”* and not *“too difficult”*. This comment may suggest that more exploration must be done on the impact of ‘not too difficult scientific investigations’ on the members’ scientific learning.

6.4.4.2 Disengagement

The questionnaire participants were asked whether they are still active members in Weather-it community. For those whose response was negative (n=17), there was a follow-up question enquiring the reasons for their dropping out. The following table (Table 27) summarises the main reasons for leaving Weather-it community.

Table 27: Self-report on disengagement

Time	This theme includes disengagement reasons in relation to lack of time, bad timing, joining the project late or intention to be active later.
Topics	Respondents were not interested in the weather topic, did not find any mission of their liking or joined for a particular mission which has finished.
Experience	Lack of experience was also one of the drop-out reasons.
Software	Questionnaire responses included software as one of the main reasons for dropping out Weather-it. More information can be found in Section 6.6 which is exclusively dedicated to the nQuire toolkit.

Time

Time was the most cited reason for dropping out of the Weather-it community. Members who liked the topic did not find the time to get engaged with the investigations and the community.

For instance, member Squamish stated that he had *“no time during the active period”* (Squamish). Some other members, such as Levanto and Barber, felt the need to elaborate more on their lack of time and provided the reasons they had no available time:

“I think the Weather-it project is interesting and has been very well promoted, and in principle I would love to take part, but I am involved in many volunteer recording projects for biodiversity and simply haven't managed to find the time to take part in this project as well.” (Barber)

Barber’s response implies that he is a citizen scientist involved in other citizen science projects. Due to his volunteering in those projects he finally did not get the time to engage with Weather-it investigations.

Member Levanto was quite an active participant, daily engaged with all the missions during the first month of the project. He then dropped out. His questionnaire response was *“I got busy with lots of stuff”* and thus he was asked to elaborate on his response during his interview. He then explained that he was a teacher in his first year in a new class and that he was also getting prepared for his wedding. These reasons were enough to not allow him persist with his participation in the initial rates.

Apart from the “lack of time” there were also people who intended to participate but did not get the chance yet, or members who joined the project in a later stage and they did not engage with any of the investigations by the time of the questionnaire. For instance, member Nacreous was one of these members.

“I joined quite late and didn't get around to participating in any of the projects.” (Nacreous)

Topic

Another important reason for dropping out was the lack of interest in the community topic or the missions. For example, although member Mistral was not that interested in weather, he joined

the community because he wanted to help in research. His 'altruistic' motivation though was not enough to keep him active in the community.

"Because I am not really into this issue, but I try to help researchers when possible." (Mistral)

Several other members, even though they were interested in weather, did not find anything of their interest in the community and thus dropped out. For instance, member Brisote wrote: *"I didn't find anything that interested me."*

Finally, some members, registered with Weather-it because they were interested in a specific mission. Once that mission came to an end, they lost their interest in the community and abandoned it.

"The mission i applied for (sun recording) ended." (Nashi)

Experience

Lack of experience as a reason for not being active in Weather-it was cited by a single member.

"I didn't know much on the subject, and due to that I wasn't sure that I could contribute to the subject efficiently." (Sumatra)

The particular member was a beginner that had *"never actually studied anything relevant to the weather conditions or even physics"* as many other members in the community. However, her concern about not being useful was obvious in her other responses. For example, she asked that the community might help beginners to participate without feeling guilty for saying something wrong, with a FAQ document or something similar.

6.4.5 Awards and prizes

Awards and prizes, as described in previous section (Section 5.5.3) were provided to Weather-it members with the best performance in order to motivate increased participation and

engagement in the community. For instance, in ‘Rain duration’ mission, the book “Introducing meteorology: A guide to weather” was given as a prize to the most voted response (Figure 73).



Figure 73: Win-it mission book prize

An initial observation was that although Win-it missions were providing prizes, they had fewer participants than Spot-it or Sense-it missions. The reason for that may be that Win-it missions involve more effort in submitting an idea than a picture or a sensor recording submission in other types of missions. Moreover, ‘prizes’ were mentioned as a positive feature in Weather-it only by a single member during her interview, suggesting it was not that motivational at that stage.

However, this behaviour changed with the last Win-it mission ‘Deserts’ where members who posted ideas were giving negative votes to other competition participants. This unusual behaviour was also noticed and criticized by other members who were not participating in the ‘competition’:

“Negative voting? Hahaha” (Stratus)

Another type of award was the prize for the top contributor and the best photographer which were changing receivers every month. Most of the members who received those prizes seemed to be surprised, however, as they were not aware of the scores during the month (in contrast to Win-it competitions) and were not expecting to receive the prize. This suggests that future design

should include a discussion on whether tables with scores would make members more competitive and engaged with the activities or would put them off contributing.

6.4.6 End of project engagement

Section 5.5.1 described the role of the e-moderator in Citizen Inquiry as essential as it is connected to not only the creation of the community but also the sustaining of participation. However, the facilitation by the e-moderator ended gradually after the completion of the project period. Thus, the communication (e.g. email updates) stopped immediately, the email notifications ran for two more weeks (Week 15 and 16) and the Facebook announcements were reduced. The last award for a Win-it mission ('Frost') was attributed about one month after the end of the project period (7/4/2015).

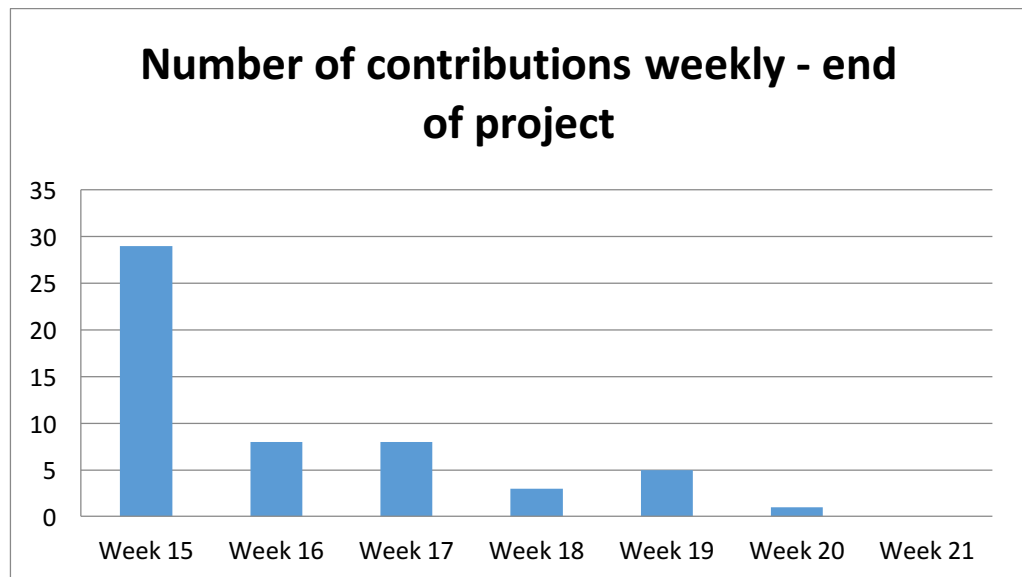


Figure 74: Engagement – end of project

Figure 74 shows the weekly activity of the community - the total contributions – after the end of the project. The number of the contributions in Week 15 is already reduced in relation to Week 14 (Figure 63, Section 6.3.6). The activity seems to gradually decreases, reaching the bottom by Week 21. An exception is Week 19 where the number of the contributions goes up again, as it was the last week for members to submit their favourite 'Frost' idea.

6.4.7 Summary

Overall, as shown in the results, Weather-it members were linked to the project for longer time (Section 6.4.1) with Relative activity duration equal to 0.43, in comparison to volunteers of contributory citizen science projects, with roughly periodic visits and their activity level was more similar to the volunteers in Galaxy Zoo. The engagement metrics, combined with findings from the survey, have produced information on the overall level of engagement and the individual engagement profiles.

The engagement profiles are labelled as follows: loyal, hardworking, persistent, lurker and visitor. The highest percentage of members falls into the 'visitor' category while 'loyal' category is recognized as the most desirable as members of this category remain both linked in and active in the project. Additionally, members who have bond-based commitment with other members in the project seem to stay linked to it the longest, and science experts tend to be in a 'visitor' engagement profile.

Members were engaging with a variety of activities and thus clustering them in profiles based on their activity was not possible. The type of activities that took place in the community were mission creation, commenting, voting, forum posts and browsing. However, many members did not become actively engaged in any activity but browsing. Moreover, some members had exceptional participation in a type of activity, for instance, creating many data items (extreme contributor), voting for data and comments (voter), and commenting on data and comments (commenter).

Factors that support members' engagement in the community include aspects around the variety in the community, the Weather-it social and interactive aspect, and the concept behind the project, which allows non-experts to conduct their own investigations in collaboration with other members and contribute to other investigations. Software is a cause of both engagement and disengagement in the community. Other reasons for dropping out Weather-it are the lack of a) time, b) interest in the topics and c) experience.

Prizes and awards did not play a significant role in members' preferences on missions and was only referred to by a single member as a positive factor in the project. An exception was a Win-it mission close to the end of the project, which sparked conflict with negative votes. Lack of a comparative scores table may be the reason that the members were not very competitive.

Finally, the reduced number of contributions after the end of the project highlights the significance of regular project communication between the members and the community moderator and emphasises the essential role of the latter.

6.5 Inquiry

This section explores Weather-it members' engagement with the scientific investigations. A first rough description of the missions took place in the overview of this chapter (Section 6.2). The investigations that unfolded for the missions are described in the following parts of this section, focusing on the relation between members and missions and analysing the features and participation of each mission. The description of the missions is followed by a more thorough examination of the individual inquiries, the inquiry behaviour, and the relationship between the members, the community vocabulary, and the reflective writing in a forum thread. The section concludes with a self-report on the members' new acquaintances from their participation in Weather-it and the experts' opinion on the project.

6.5.1 Members and Missions

Weather-it members were voluntarily participating and were free to choose their activities based on their preferences. As a result, not all the activities had the same participation. The mission with the largest number of memberships is the 'Identify the cloud' Spot-it mission, with 41 memberships from Weather-it people. The second most popular mission is 'Record the sunlight' Sense-it mission with 27 Weather-it members. The third place is shared by three missions with 16 members each: 'Snowflake spotting' and 'Sunsets' Spot-it missions, and 'Earth Vs Mars' Win-it mission.

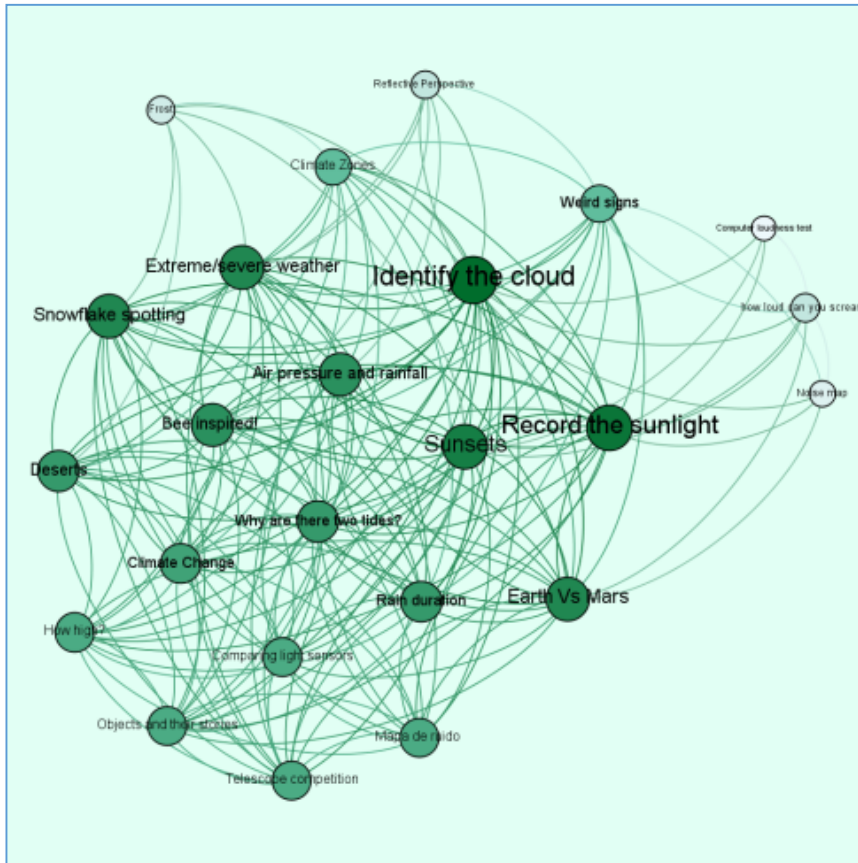


Figure 75: Co-joined missions by Weather-it members

Figure 75 shows the interconnection between the co-joined missions, with the largest memberships also being the most weighted. The least connected missions, which are also shown to be peripheral in the graph are 'Frost', a new Win-it mission, and four non-Weather-it missions joined by Weather-it members (Computer loudness test, Noise map, reflective perspective, how loud can you scream?). The 'Bee inspired' Win-it mission, although it is a non-Weather-it mission, seems to be well interconnected with the Weather-it missions and joined by the members. However, the Google Analytics page-view reveals that the largest number of pages that visitors looked at on the nQuire-it site is for the Spot-it missions 'Identify the cloud', 'Snowflake spotting' and 'Sunset' with 2525, 1001 and 435 views, respectively.

Figure 76 shows the missions which tend to be chosen together, separated in Sense-it (blue), Spot-it (green) and Win-it (red) mission types. The graph suggests that none of the mission types is dominant as they cover almost equal percentages: Win-it 37.5%, Sense-it 33.3%, and Spot-it

29.2%. Moreover, the modularity algorithm equals to 0.08, indicating weaker ties within the mission types and stronger ties with other mission types.

We can see that the Weather-it members may be interested in a single Weather-it mission and this might also be the reason they have joined the community, but we can also see members who are interested in general in investigation and they join not only weather missions, but also other missions available on the nQuire-it platform. The three Spot-it missions that have the greatest page-views from Google Analytics, may also indicate that this kind of mission attracts many visitors to the nQuire-it platform. However, a Sense-it mission which required daily participation for a month (Record the sunlight) possesses the second spot within the Weather-it preferences. Finally, the overlap between the missions of different types shows that the Weather-it members are interested in joining missions of any type of data collection.

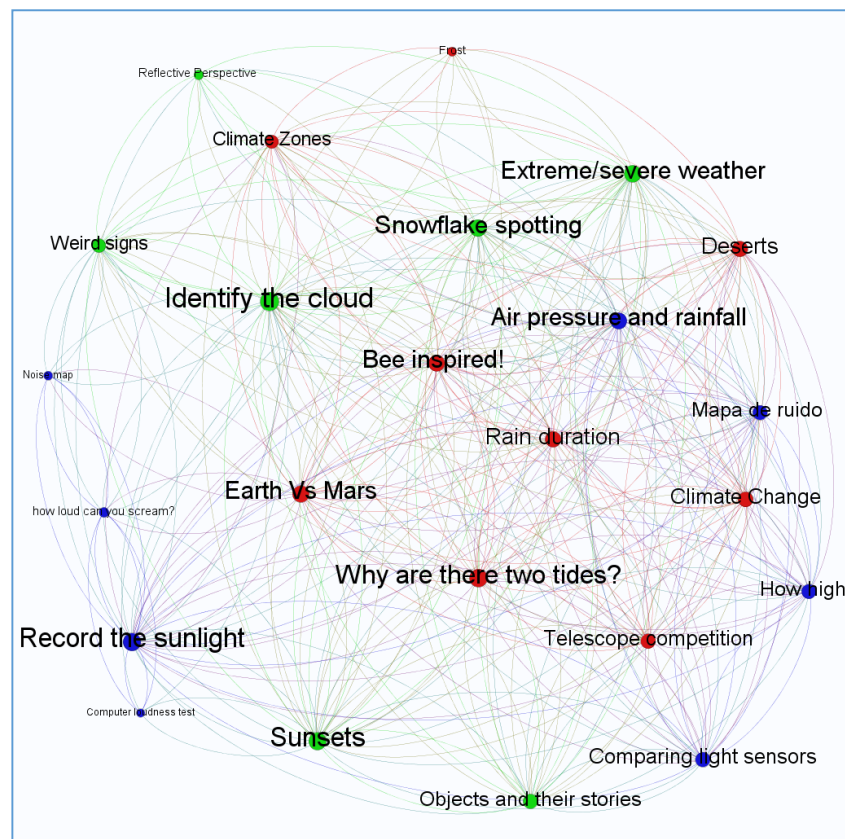


Figure 76: Co-joined missions, colour-coded according to the mission type

6.5.2 Exemplar missions

During the preparation of the Weather-it project and at the pre-birth stage of the community, three missions, one of each type, were created as examples for the members and as activities for the first members to start with. This section describes the inquiry routes that these missions went through from their creation to the end of the mission (Sense-it, Win-it) or the end of Weather-it project.

Record the sunlight Sense-it mission was intended to be of short duration and was facilitated by the moderator, with 146 contributions. Within the data, there were eight invalid measurements (5%), identified from the wavy plots, which were removed from the analysis. The measurements were from eleven different places in Europe (Milton Keynes, Oxford, Stockholm, Athens, Belgrade, Liege, Lausanne, Barcelona, Limassol, Central Greece and Great Missenden) ranging from 2 to 37 readings and 1 to 5 people measuring in each place. Graphs were produced for the measurements in every location indicating the variation in readings for the period and the average Lux. According to the final results, Limassol had the highest average sunlight for that time interval and Stockholm the lowest (Figure 77).

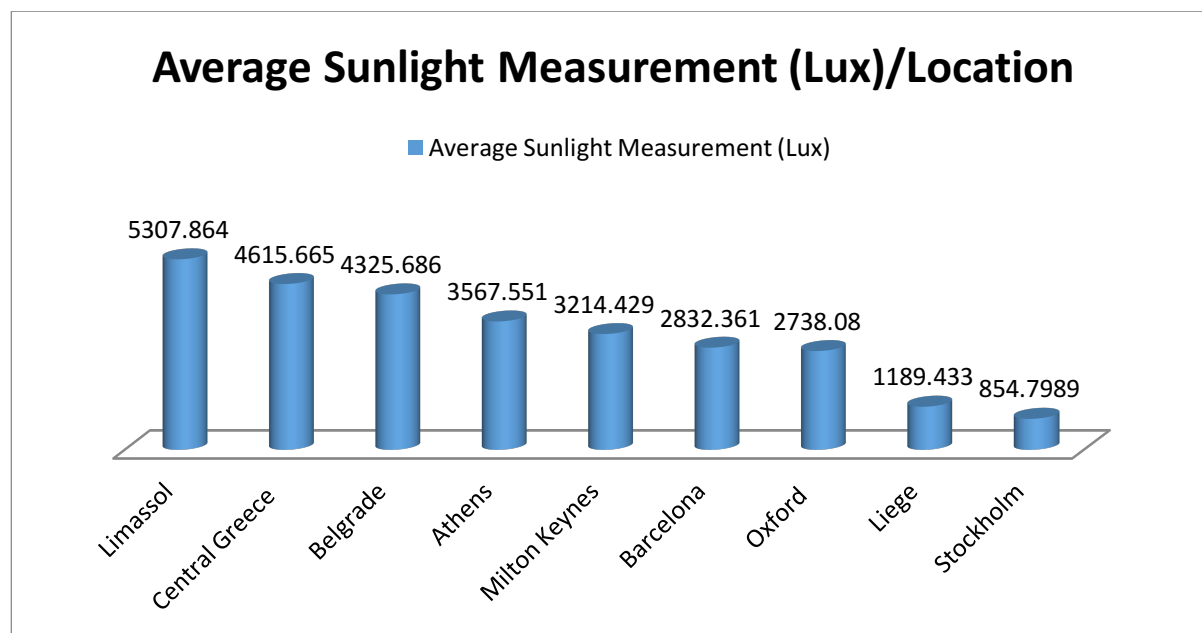


Figure 77: Average light levels for cities measured on the Record the Sunlight mission

Identify the cloud Spot-it mission was designed for spotting and identification of clouds with the help of the cloud spotting guide (MetOffice) or the community. As Spot-it missions are open-ended and accommodate many inquiries, ‘identify the cloud’ became the most popular mission in Weather-it, counting 41 active participants and 159 inquiries – only Weather-it members included. Of those picture inquiries, almost three quarters (112) received identification responses and slightly fewer than half (65) had follow-up comments on the identification. Also, two out of three best photographer prizes were won by cloud picture owners (members Cirrus and Zephyros). After the end of the Weather-it project duration 25 more picture inquiries were added to the mission by Weather-it and non-Weather-it members.

Earth Vs Mars Win-it mission was suggested as a challenge by an expert in planetary atmosphere modelling and the question was *“Why do you get colder going up a mountain on Earth, but you wouldn’t on Mars?”*. The members had to complete their inquiry in four steps and then publish it. Thus, they had to describe how they would organise their research, describe the collected data, describe the resources they had collected the data from and write their final answer. Four ideas were produced and two out of four received votes. The expert who had suggested the mission, reviewed the ideas, spotting correct and wrong ideas, and finally published the correct answer which agreed to the most voted one. The most voted response belonged to member Norte who won a £20 Amazon voucher.

6.5.3 Weather-it Missions

This section outlines the activity taking place in the three different types of missions, focusing more on the most popular mission of each type. The ‘example missions’ were the most popular of their mission type that were created by Weather-it members. More detailed descriptions of the inquiries that took place within the missions can be found in the following sections.

6.5.3.1 Sense-it missions

Creating Sense-it missions was not as popular as other types of missions, probably because it required more effort and familiarity with the Sense-it application. More information about the

use of Sense-it application is provided in the following section ‘nQuire toolkit’ (Section 6.6). As a result, except from the exemplar ‘Record the sunlight’ mission, only one more Sense-it mission was created.

Air Pressure and rainfall recorded 16 contributions in a period of 5 weeks. The contributions were made mainly in Milton Keynes, with one exception which was made in London, by four people. The conclusions of the analysis by an nQuire-it member (the analysis was not published on the platform) has shown that in most of the cases the less the pressure the rainier the weather. However, there were two measurements not following this observation. Although this mission was available for as long as the ‘Record the sunlight’ mission, it was less popular as not many mobile devices supported a barometer and the results were not enough for a clear conclusion. More contributions – 18 more – were recorded after the end of the Weather-it project, showing no clear relation between air pressure and rainfall while identifying calibration issues with the air pressure sensors (Sharples et al., 2015).

6.5.3.2 Spot-it missions

Spot-it missions were the favourite ones as they attracted the largest number of participants. The following table outlines the participation in each of the Spot-it missions (Table 28). As shown in the table the most popular Spot-it mission was the exemplar ‘Identify the cloud’ mission. The second more popular, created by the Weather-it member Ostria, was ‘Snowflake spotting’.

Table 28: Participation in Spot-it missions

Spot-it missions	Participation
Identify the cloud	41 Weather-it members created 159 inquiries and 5 mission comments
Snowflake spotting	22 Weather-it members created 88 inquiries and 13 mission comments
Extreme/Severe weather	9 Weather-it members created 2 inquiries and 1 mission comment
Sunsets!!!	16 Weather-it members created 17 inquiries and 8 mission comments

Snowflake spotting was aiming to explore, around the spotted snowflakes, how the air temperature affects the snowflakes' shape and size. Snowflake spotting is an open-ended Spot-it mission and thus received 88 picture inquiries during the Weather-it project and engaged 22 Weather-it members. Of the picture inquiries, almost one third (27) received comments and only 18% had follow-up comments. The participants in this mission seemed to be more interested in the artistic aspect rather than the scientific, as the comments do not involve efforts to identify the snowflakes' structure. An exception was a late joined member, Taku, who sparked the interest in snowflake identification methods to other members too. Picture inquiries after his arrival involved more scientific comments. After the end of the Weather-it project duration 24 more picture inquiries were added to the mission by Weather-it and non-Weather-it members.

6.5.3.3 Win-it missions

Participation in Win-it missions is outlined in Table 29. The column 'members' indicates the number of people who have a membership in the mission and not those who were active.

Table 29: Participation in Win-it missions

Win-it mission	Members	Ideas	Mission Comments	Votes	Completion	Comments
Earth Vs Mars	17	4	7	5	Complete	Four inquiry phases were included in this mission: 1 member completed all of them, 1 completed 3 phases and 2 completed only the 'answer'.
Rain duration	10	6	4	9	Complete	This mission had only one inquiry phase, the answer.
Climate Change	11	2	4	5	Complete	This mission had two phases. The 'resources' phase remained incomplete in both ideas.
Climate Zones	8	2	2	-	Incomplete	Three inquiry phases were included in this mission. Both of the idea contributors had only completed the 'answer' phase.
Deserts	13	6	6	14	Complete	This mission had only one inquiry phase, the answer.
Frost	8	2	1	7	Complete	Both of the idea owners completed only one out of four inquiry phases.
Why are there two tides?	7	2	7	0	Complete	This mission had only one inquiry phase, the answer.

In all the missions, the creators chose that each member is only allowed to submit one idea. The mission owners were also maintaining other options such as the number of inquiry phases (e.g. resources, methods, analysis, answer) and mission stages (submission and voting, winner announcement). The communication was taking place in the mission comments and sometimes in a forum thread with the same name as the mission topic. In the column 'Completion' it is indicated whether a mission reached its end and thus completed all the mission stages – idea submission, voting, and winner announcement. 'Climate zones' was the only mission that remained incomplete as the owner stopped maintaining it. All the other missions went through all

the stages and are considered as complete. Although the mission creator may have set up more than one inquiry phase, in most of the cases the idea contributors preferred to skip the phases that describe the methods and resources and submit their answer without providing any information about their research process. The most popular missions based on the number of the submitted ideas were 'Rain duration' and 'Deserts'. The latter one is described in a previous section (Section 6.4.5) as it demonstrated interesting behaviour in relation to the voting stage.

The **Rain duration** question was *"Which factors can you think of that determine the duration of rain at one specific location?"* and received eight ideas. Of those, four have received votes (1 to 4) and two were submitted by non-Weather-it members. The creator of this mission had not set up more than one inquiry step for the idea submission and thus the participants published their response without any other information relating to their resources and methods. The mission duration was about 5 weeks for the submission stage and two weeks for the voting stage. Alongside the mission, a forum thread with the same name was created for further discussion and hosted eight forum posts. At the end of the voting stage, the mission creator, who was a master's student in meteorology at that time, commented on each idea individually, spotting the correct and incorrect points of every submission. Member Brisa, according to the mission owner, listed roughly the five very important factors of rain duration. She was also the one with the most votes and therefore she was the one to win the mission and receive the book prize.

6.5.4 Types of learning

In this section types of learning through the participation of Weather-it members in the missions were identified. Gaining and providing weather knowledge, annotation and identification skills for weather data, and detecting and breaking down misconceptions were part of the learning process in the community. The following examples include participation snapshots by two beginners (Cumulus, Boreas), two intermediate (Stratus, Fremantle) and two experts (Ostria, Norte) that propose evidence for each type of learning.

6.5.4.1 Weather knowledge

Content knowledge on weather happened through the participation of members in discussions around the inquiries. The on-topic learning in Weather-it depends on the existing weather knowledge level of the participants. Thus, some members were engaged in learning about basic weather content and some others, more advanced, furthered their existing knowledge.

a) Basic knowledge

Member Cumulus was a beginner who liked to interact with other people and participated in inquiries with many basic weather knowledge questions. For instance, Cumulus posted a comment below a sunshine picture (Cumulus-1) showing her surprise towards a London sunset. She also observed that the colour of the sunset is “yellowish” but did not proceed to any other explanations or inquiries.

"I didn't expect you could see a sunset in London. Is it a bit yellowish?" (Cumulus-1)

In another item, member Norte mentioned the possibility of ‘distrails’ in a cloud picture. Norte described the distrails as a rare phenomenon that looks as if planes pass through the clouds. Cumulus then, observed in the picture that there was more than one stripe and asked whether it was possible for a single plane to create all of them.

"I think there is more than one stripe, how it comes? Multiple planes or the plane's heat can create more than one stripe?" (Cumulus-2)

"If these are truly distrails, then multiple plane passages were involved (one stripe per passage)."
(Norte)

Cumulus understood what the ‘distrails’ phenomenon is about and replied with that question to gain more information. Norte highlighted again that the picture may not be showing distrails, but in the case it does, then it is more likely that multiple planes created the multiple stripes.

The next comment was on the 'Deserts' mission. Cumulus was trying to figure out why deserts are not found at the equator where it might be expected to be the hottest. Although she attempted to guess the answer (Cumulus-3), she preferred to post her thoughts in a mission comment rather than to compete with the other posted ideas.

"Because earth rotates so that equator is not vertical to the sun but diagonal?" (Cumulus-3)

Although her comment was incorrect and she did not receive any response, Cumulus was still interested in the correct answer and the voting stage of the mission.

b) Further knowledge

Fremantle is a member of intermediate weather expertise and a sailor. He had mainly shown interest in a single mission, 'Why are there two tides?', and his participation was focused around it, seeking to further his knowledge on the topic. He got engaged in discussion in relation to the factors that cause two tides a day, questioning the role that centrifugal force plays to the spring tides and neaps.

"OK, so centrifugal force overcomes the gravitational attraction to give roughly two tides a day. How does that explain springs and neaps? The range (height difference between high and low water) is different every tide at a particular place on a "lunar" monthly cycle. Spring tides (largest) range occur at full moon and no moon (when the sun and moon are roughly in line) and neaps (lowest range) when sun and moon are at right angles to each other with respect to the earth. Not sure how the "centrifugal force" would work out in these situations??" (Fremantle)

Fremantle's comment came forward as a response to the posts that have been placed as ideas to the Win-it mission and sparked the discussion. He seems to acknowledge that centrifugal force is one of the important factors but reacts by replying with further questions, evaluating the posted ideas and challenging for further inquiry.

6.5.4.2 Annotating weather data

Several members in Weather-it were attempting to annotate their data in order to describe their settings. Data annotation is argued to be a very important part of communication among scientists (Bose, Buneman & Ecklund, 2006) and even more for collaborative research (Gertz, 2002). The nQuire-it platform does not provide an automatic system and thus the members had to do it manually after following the mission instructions and other exemplar data descriptions. The annotation could either be in the title of the contribution or as a comment in the data item.

Beginner member Boreas was mostly engaged with two Spot-it missions 'Identify the cloud' and 'Snowflake spotting'. Boreas' favourite activity was to post his own data with included information about the item in the picture. Information usually included location and time, while snowflake pictures also informed about the temperature at the time of the capture.

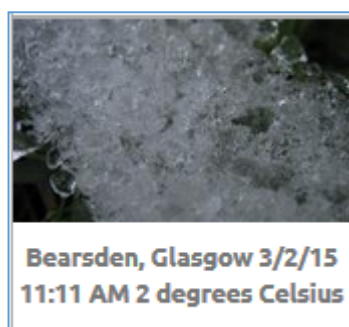


Figure 78: Annotating weather data

The fact that Boreas was adding temperature to his snowflake captures indicates that he had done his inquiry on the factors that affect the snowflake types (Figure 78). The changing temperature within the atmosphere is one of the factors that influences the different patterns and structures of snowflakes (Libbrecht, 2004).

Expert member Ostria participated mainly in the same missions as Boreas 'Identify the Cloud' and 'Snowflake spotting'. She also seemed to be particularly interested in snowflakes as she was the creator of the mission. Her interest was also shown by the fact that her favourite activity was to vote for the well-taken pictures of snowflakes. Although she is an expert in weather she was a newcomer in the snowflake spotting and thus she had also uploaded some pictures trying to

identify the types of the items. For instance, in the comment below she described her item with date time and temperature, and then she recorded her observation in relation to the item's structure.

"Photo taken 02/02/15, approx. 23:00. Temperature around zero degrees C, snowflakes observed to be general clumps of ice crystals (no distinct structure visible)." (Ostria)

Notable is that earlier items she had uploaded were not described in such a detailed manner. Her new method of recording her observations might have been adopted by Boreas, the member that constantly described the snowflake items with location date and temperature.

6.5.4.3 Identification methods

Several missions, mainly the Spot-it ones, were requiring the identification and further classification of the inquiry items by the members. Such missions were the 'Identify the cloud', 'Snowflake spotting' and 'Sunsets'. For the identification, members had to follow some identification guides or/and do their own research. The following examples of identifications derive from the three above-mentioned Spot-it missions.

a) Clouds

Boreas participated in discussions below pictures that portray clouds and snowflakes, trying to identify their types. For instance, in comment Boreas-1 he expressed his guess about the type of a cloud in a picture.

"Cirrus would be my guess." (Boreas-1)

In comment Boreas-2 as well as identification he also provided an explanation on how he concluded to his answer.

"I would say that one big grey cloud is a cumulonimbus." (Boreas-2)

His identification seems to follow inductive reasoning as he recognised that big grey clouds are usually cumulonimbus. Unfortunately, he had not received any follow-up responses to his comments that would accept or reject his identifications for those items. However, in a later discussion of the moderator with an expert for the needs of this analysis, it was shown that statement B1 was correct but statement Boreas-2 was incorrect.

Boreas, although he did not receive any responses, got engaged in discussions over some other items. An example is the identification of two cloud items in a picture that he had posted. Member Stratus identified the items with an informative/starter comment below the picture and Boreas responded to those identifications by acknowledging the information with an accepting comment. An expert approved the identification.

"Stratus and Cumulus?" (Stratus)

"Yes that sounds right" (Boreas-3)

Similarly, Ostria attempted to identify the cloud picture items, recognising two types of clouds (Ostria-1). With her description it is indicated that she recognises cloud shape and altitude as a factor for categorising clouds. A cloud expert (Norte) acknowledged her response and agreed with her identifications.

"Looks like there might even be two types of cloud here: the slightly more fluffy altocumulus, and then some wisps of cirrostratus behind it? (Hard to tell what height they might have been!)"

(Ostria-1)

"I agree!" (Norte)

A second comment by Ostria (Ostria-2) had also a follow-up comment by the same cloud expert, Norte.

"I'd guess Stratocumulus in the foreground (with altostratus hiding behind them?). Maybe stratus over at the horizon, but it's hard to get an idea of scale when looking that far away." (Ostria-2)

"There are some altostratus in the air (the white ones) and some stratocumulus (the grey ones). But they are not very distinct features and we can hardly categorize them." (Norte)

Both Ostria and Norte identified the stratocumulus and altostratus clouds with Norte being uncertain about the categorisation as the cloud features are not that distinct. However Ostria's and Norte's potential categorisation match as the "foreground" clouds are "the grey ones". Ostria had also attempted to identify the lowest clouds that the cloud expert member avoided, more likely because of the unclear characteristics.

Likewise, in comments Stratus-1 and Stratus-2, Stratus (a member of intermediate expertise) tried to recognise some cloud types. From his comments, it is clear that parts of his identification methods were the shape and the altitude.

"How high are they? Altocumulus unless if they are of a higher level." (Stratus-1)

"Iridescent unless if the camera was blurry?" (Stratus-2)

Stratus in the above comments suggested identifications but asked the item providers more questions about the settings of the cloud captures. Unfortunately, he did not receive more information and thus his identification effort on those items remained stationary. However, he kept being engaged with others' investigations. For instance, in a cloud picture member Suestado identified the clouds as "stratus fractus" giving away information about their shape and acceleration:

"CL7 Stratus fractus? They started as smaller patches... Moving fast below other clouds." (Suestado)

"Yes, they look like scuds of stratus fractus. Should have been a rainy day? :)" (Stratus-3)

Stratus responded to Suestado's comment with acknowledgement and acceptance. His response indicates evidence of his further knowledge on clouds' importance on everyday weather.

b) Snowflakes

In another discussion, Boreas is trying to identify the type of snowflakes on a pair of gloves. In this effort he receives an evaluative response by a more expert member.

"At a complete guess I would say these are plane crystals with column-type." (Boreas)

"In these large sizes I believe it is always a mixture of various crystal types. A lot of "things" stick to the snowflake before it reaches the ground." (Norte)

The comments by Boreas indicate his effort to recognise the aspects that count for the identification process and take part in the discussion and inquiry. Remarkable is the uncertainty that characterises all of his comments with the extent use of words/phrases such as *"guess"*, *"complete guess"*, *"I would say"*, *"sounds right"*, *"I think I am not sure"*, etc.

c) Sunset

Stratus participated in the 'Sunsets' mission, trying to understand the sunset colours. In comment S2 there is an effort of explaining why the sunset in the picture is an orange colour. In this effort, he mentioned a piece of uncertain information by which sea sunsets should have orange colour, but his comment did not receive any responses.

"This is an orange one. Orange goes to the sea sunsets, then?" (Stratus)

This comment might have come forward after some research Stratus might have done on the internet. Some sources support that salt particles in the air have orange sunsets as a result (Gibbs, 1997). His comment suggests that he realises that there are some factors affecting the colour of the sunlight and sea (or sea particles) may be one of them.

6.5.4.4 Diagnosing misconceptions

Learners in science education are taught how the reasoning process leads to conceptual generalisations. However, sometimes some preconceived notions are created rooted in everyday

experience which prevents learners from understanding a phenomenon. The following example mirrors a misconception coming from a Weather-it member.

Stratus had also created his own Spot-it mission on 'Extreme/severe weather'. After he received some contributions to his mission, he came with a comment that reflected his perception of the severe weather locations:

"Thank you for your Thunderstorm and Flooding pictures! they are both from southern countries, I expected cases from northern places." (Stratus)

By that point, the posted items came from countries such as Cyprus and Morocco presenting phenomena such as thunderstorms and flooding. Stratus' comment shows his reaction towards the new unexpected knowledge.

6.5.5 Inquiry patterns

Weather-it involved members of different levels of weather expertise (Chapter 3.3.). Thus, we had weather expert and non-expert members interacting on nQuire-it and collaborating for the investigations. This section analyses the patterns of interaction between and within the two groups.

6.5.5.1 Imitation

One of the behaviours that was noticed in Weather-it was non-experts imitating experts. The following comment has been made by an expert below a picture with a cloud item. The picture was showing a "very faint cloud" on the sky (Figure 79). An expert's comment on that picture focused on the fact that the horizon was not captured and thus the altitude cannot be estimated. This comment took place on the 22nd of January.

Norte: *"Please try to capture the horizon in your picture so that we can roughly estimate the altitude of the clouds."*

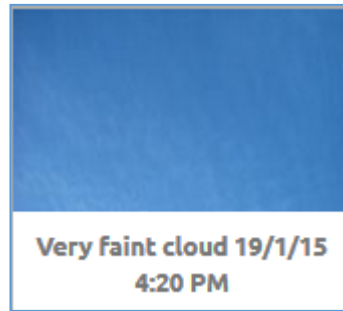


Figure 79: "Very faint cloud" picture without horizon captured

Nearly a month later (18th of February), a non-expert member, who until that time had not made any efforts to identify clouds and declared herself as ignorant as to cloud identification, comes with the following comment on another cloud picture:

Cumulus: *"It is maybe better to include the horizon in the picture so we can understand how high it is. However it looks like cumulus or Stratocumulus."*

This is an example of imitating experts' way of recognising the cloud category. Altitude is one of the main factors for cloud identification. Member Cumulus managed to register this information and then "copy" this method for her own identification efforts.

6.5.5.2 Information

Some other interactions between expert and non-expert members were mainly informative, transmitting knowledge from the one group to the other. For instance, the following dialogue began with an informative comment by an expert on a cloud item. The expert explains how a status and a nimbostratus cloud may differ by giving their definition in the English language.

Brisote: *"Great example of stratus cloud. If it was raining then it's a nimbostratus cloud. nimbo means rain and stratus means covers the whole sky. These are my least favourite clouds!"*

Cumulus: *"So the words are meaningful?"*

Brisote: *"Yep they are meaningful. I think the names mostly come from Latin and described the height and distribution of the cloud. Wikipedia has more - http://en.wikipedia.org/wiki/List_of_cloud_types"*

Cumulus: *"Oh! I've never thought to google it. Thanks Brisote! Keep informing us!:D"*

Member Cumulus expressed surprise at the expert's comment and asked for more information. The expert informs that the widely spread-used names come from Latin and provides a source for those who want to learn more about their meanings. Cumulus seems to be inexperienced on the topic but satisfied with her new piece of knowledge,

6.5.5.3 Acknowledgment

Several interactions were between people of the same level of expertise. In the following dialogue there is an example of an expert to non-expert interaction. An expert (Norte) identified the cloud item in the picture and then a non-expert (Barat) acknowledged the answer and agreed to the identification while providing some more information.

Norte: *"Cumulus"*

Barat: *"Convective bank of cumulus. I can agree with you Norte."*

In a second dialogue, there is an example of non-expert to expert interaction, where the non-expert identifies the cloud item of the picture and the expert acknowledges her effort and provides some more information about the identified cloud.

Sharki: *"a cumulonimbus"*

Arcus: *"Nice winter cumulonimbus cloud. During late autumn and winter strong convection develops across the English Channel when colder airstreams (such as polar maritime air arriving from the northwest) cross the warm seas. Significant increase of wind with height (wind shear) causes the upper (anvil) part of the shower cloud to shear downwind."*

6.5.5.4 Mentoring: experts to non-experts

Mentoring by experts was the most common type of interaction between experts and non-experts. Experts were willing to provide information about the cloud identification methods. In the following dialogues, experts provide corrections and guidance to non-experts.

Example #1

Undulatus: *"Can I try? Is it "Noctilucent clouds in the night sky" this one?"*

Norte: *"By their dark color we can tell that they are low clouds. Noctilucent would be very high and white due to the light they get from the below-the-horizon sun."*

In this first example, a non-expert made an effort to identify a night cloud item. The use of quoting marks shows that she looked it up in a cloud identification guide and then posted the exact term below the picture. Norte, the expert, provided feedback on her identification, explaining the reason why it is incorrect.

Example #2

Norte: *"Just stratus probably."*

Maria: *"How do you know? it's so cloudy that I cannot even see a cloud formation."*

Pali: *"Stratus can be sheet like and featureless. Given that some trees can be seen clearly I hazard a guess that the sky is not obscured by fog - so probably stratus unless you have a better indication of cloud height."*

In this second example, the dialogue started with a cloud item identification by the expert member Norte and a follow-up question by the moderator, Maria, who is a non-expert. Maria asked more details on how the expert came to that identification. The conversation continued with a response by a second expert, Pali, who explained on behalf of Norte by giving more information about the structure of "Stratus" clouds and how it fits with the cloud in the picture.

6.5.5.5 Mentoring: non-expert to non-experts

However, experts did not have exclusive rights to mentoring as in some cases, but not many, non-expert members with some experience of weather were providing advice to other non-expert members. In the following dialogue, there is a discussion between three non-experts members below a picture with snowflakes (Figure 80):



Figure 80: 'Snowflake spotting' picture

Taku: *"Lighter snow than expected, at -7 degrees C and 83% humidity the snowflakes should be from the COLUMNS group including Needles, Hollow Columns and Solid Prisms."*

Stratus: *"Can you say their types without a microscope or something?"*

Taku: *"I used the morphology diagram to identify the snow flake types they possibly are."*

Cumulus: *"Can you post a link to it? Are you an expert or can we recognise them too?"*

Taku: *"I used the snowflake morphology I found here:*

<http://www.its.caltech.edu/~atomic/snowcrystals/primer/morphologydiagram.jpg>"

Taku: *"I used temperature in the morphology diagram to identify potential snowflake types. I could not convert relative to absolute humidity to narrow down the snowflake types more precisely using the morphology diagram. Using -7 degrees C, 93% relative humidity converted to g/m³ the snowflake type should be needles according to the snowflake morphology diagram."*

From this dialogue, it is clear that although all the discussion participants are non-experts, Taku has more knowledge on how to identify the snowflake types. After he posted the picture with the snowflakes, he tried to describe more the weather conditions the snowflakes were formed in; he referred to both temperature and humidity levels. Then, members Stratus and Cumulus tried to receive more information about the identification methods. As a result, Taku informed them about the tool he used for the identification (morphology diagram) and advised them about the entire procedure and the method steps he followed.

6.5.5.6 *Opposition: expert to expert*

Another piece in the interaction pattern was the opposite to some of the identifications. In the previous section there were cases where the expert did not agree with the non-expert's identification. As a result, he responded with a comment in the form of advice relating to the incorrect identification. However, in some cases there were experts with conflicting identifications for the same cloud item. An example is the following pair of comments by the expert members Norte and Arcus.

Norte: *"Stratus here (where the picture was taken), and nimbostratus in the horizon."*

Arcus: *"Looks as if this may be a developing cumulonimbus, in view of the dark base and some precipitation trails falling in front of the clearance in the distance."*

Norte was the first to provide identification for the cloud item and then Arcus provided a different one. However, Arcus did not direct his response to Norte nor came into conflict with him. The above does not even form a dialogue as the two experts made individual comments without responding or arguing with each other about the correct answer. That was the interaction pattern in all the conflicting identification comments – that have been spotted – between experts.

6.5.5.7 *Opposition: non-expert to expert*

A more interesting type of interaction was that of a non-expert being opposed to an expert's identification. The members' level of expertise was not available to the other members and thus they could only judge themselves whether somebody might have been an expert. The following dialogue unfolded below a cloud picture and is an example of this type of opposition. Expert member Norte identified the items as 'stratus' clouds but then a non-expert member (Stratus) doubted the identification with a question about the altitude of the clouds.

Norte: *"Stratus"*

Stratus: *"Aren't they too high to be stratus?"*

Barat: *"Did they cast any shadows; they might be altostratus."*

Brisote: *"I would agree with altostratus."*

Subsequently, another non-expert member (Barat) provides a different identification articulating his thoughts about the role of shadow in recognising the type of cloud. A second expert member (Brisote) came to approve Barat's identification and oppose to the first one given by the first expert member. There was not any further argumentation.

6.5.6 Community vocabulary progress

Language constitutes a part of the scientific culture and evidence that members endorse the language of the field. This section investigates the language within the community, exploring whether there was a vocabulary progress during the Weather-it project period.

Further analysis of the frequently used vocabulary focused on the progress of the language week by week. Word clouds were produced exhibiting the words that the community used at least twice every week. The method was not that successful as the amount of words during the second stage of the community evolution (see Section 6.3.5) was insufficient to produce comparable word-clouds. However, some comparisons between weeks were still available.

The following pictures (Figure 81) show the vocabulary of the first (left) and second (right) week in Weather-it community. The darker and larger the word the more important it was during that period. As shown, the dominant words during the first week were types of clouds, such as 'stratocumulus' while in the second week more generic words, such as 'cloud' and 'rain', appeared.



Figure 81: Word-cloud vocabulary for week 1 (left) and week 2 (right)

Looking back at the characteristics of the first week, it was noted that the participants were the core group members, interested in weather who agreed to participate in the project deliberately and after being informed thoroughly about it. Thus, it is possible that the core group, who were the only members of the community during the first week, were more focused on the tasks. On the other hand, more members joined the community during the second week, who were still discovering the community and its potential and therefore a more broad vocabulary was produced.

An interesting word-cloud (Figure 82) was the one produced by the vocabulary of the last week. In this last snapshot of Weather-it community, words like 'degrees', 'morphology', 'diagram', 'humidity', etc. appear in the dominant, largest words, giving a more scientific nuance to the community vocabulary.

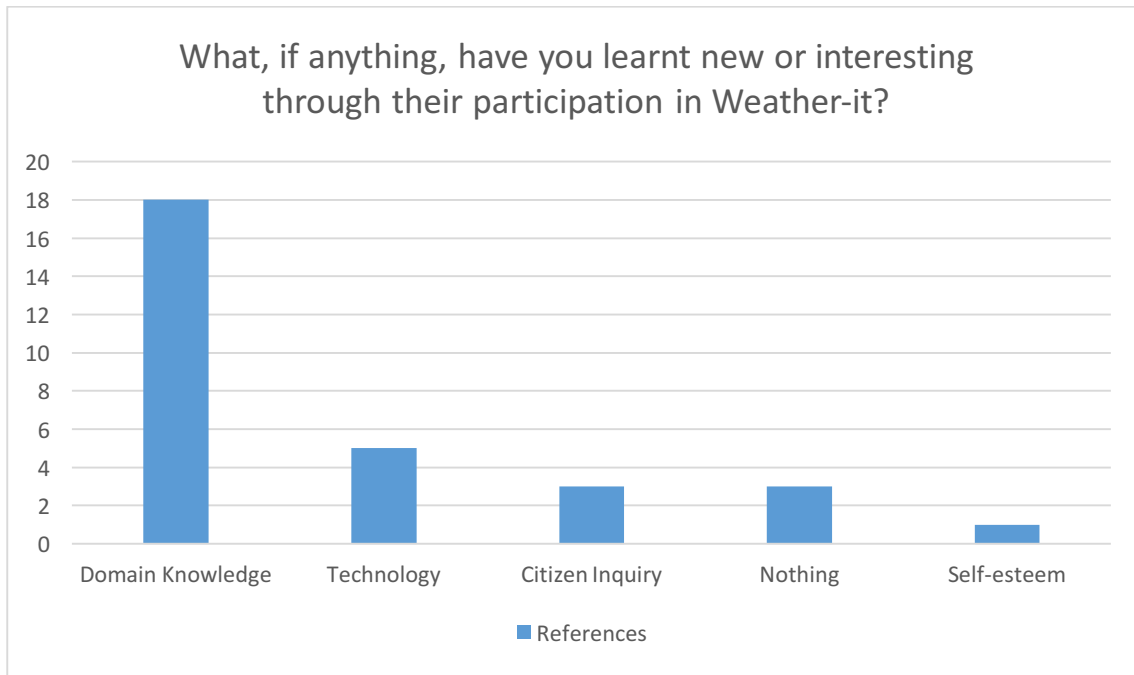


Figure 83: Weather-it – what have I learned?

Over half of the respondents stated weather knowledge as the outcome of their participation in Weather-it community. The responses included learning mainly about clouds – cloud formations, cloud names and cloud identification.

“I have learned that clouds can give us weather predictions!” (Tramontana)

“I’ve learned a few things on different categories of clouds which seemed interesting.” (Funnel)

Several respondents outlined how they learned about more than one topic as they had joined more missions.

“That there are mixed types of clouds and some more interesting information from the forum about waves and severe weather.” (Levanto)

“I learnt about clouds and atmosphere on Earth and Mars.” (Sundowner)

Five members mentioned technology aspects in their responses, mainly for expressing their surprise about the technology potential.

“I’ve learned about the sense information monitored in a smart phone.” (Fremantle)

However, some other members focused on the big picture and the philosophy behind Weather-it. Three respondents, all experts, expressed their thoughts about Citizen Inquiry, its existence and potential.

"People who have no meteorology degree can take initiatives too :) and maybe, in the future, they will have some good ideas about questions or solutions." (Euros)

"It confirms the potential resources of peoples' experiences." (Arcus)

"The existence of this type of outreach." (Mammatus)

An individual had a self-reflection and talked about her fear to participate actively in the community.

"That I was concerned that I wouldn't make a valuable contribution!" (Sumatra)

Finally, a member who also participated in Inquiring Rock Hunters provided a comparison of the learning experience in the two communities:

"It would be nice to have a variety of types of Missions - some that need to be planned more like the Rock Hunter and some that can be done from inside. This may then encourage people to extend themselves and do "deeper" research like the R[ock] H[unters] one. I liked the RH one as it gave you headings, tests etc. to choose and so guided you. However the Weather-it was very enjoyable as it made me think, and find answers to things I might not have known 😊." (Brisa)

6.5.8 Experts opinion

Alongside Weather-it members, expert members were also asked to express opinions about the Weather-it project. The following table (Table 30) shows themes that emerged through the thematic analysis of the interview data.

Table 30: Themes emerging from the experts' interviews

Potential	Comments around the current and future potential of such a community
Satisfaction	Experts express their satisfactions in relation to the project design, participation inquiry levels and variety of topics in the community
Inquiry	Evaluation of the Inquiry and Discussion levels within the community
Benefits	Identification of community benefits for weather experts.
Suggestions	Suggestions for enhancing the inquiry and increasing the participation and the discussion within the community

Potential

Weather-it was set up as a citizen participation community that allows citizens to join investigations or conduct their own inquiry and invite other people to join. The interview feedback from the experts identified the potential of the community in relation to different aspects.

"I think it has huge potential. [...] the potential is there for it being very effective in appealing for information of severe weather events." (Arcus)

Arcus detected a scientific potential of the community in reporting severe weather events while Norte acknowledged the learning aspect of the community:

"It is a great opportunity to learn things while relaxing in your free time." (Norte)

The same interviewee highlighted the citizen participation side of the community and that the creation of interesting investigation topics may encourage people to participate in science.

"All it took was to have an idea of a weather subject that would gain the attention of the members and would encourage them to engage." (Norte)

Satisfaction

The interviewees expressed their positive feelings about aspects of the community such as the community, the technology, the missions and the members' attitude.

"It is very effective and well organised community with well-behaved members." (Norte)

Norte had also created a Win-it mission, invited other members to join and received several ideas for his inquiry. He found the creation and maintenance of the mission straightforward:

"It was very easy to create the mission and maintain it until the voting stage. The platform is very well structured and everything was clear." (Norte)

Arcus was satisfied with the variety of weather topics within the community:

"There were also a good variety of weather topics featured – from Weather sayings to clouds and instruments." (Arcus)

One of the primary goals of Weather-it was to engage people with the investigations. Norte states this goal was successful as the participation levels were high and people were trying to take part in the inquiries in many ways:

"There were people (experts and non-experts) that enthusiastically attended every mission. This means that Weather-It succeeded in its cause. It was overwhelming to see that people made their research and tried to answer in weather-related questions (away from their fields of study) or participate in the data collection missions." (Norte)

Inquiry

Interviewees also made comments relating to the inquiries, and the discussion that took place within the community members. An expert described the months that the project took place as of

“relatively uneventful nature” that should have reduced the scope of the weather investigations but surprisingly, he noticed that there were many discussions and observations happening.

“Longer hours of daylight and daytime warming overland means the summer half year generally sees more variety of cloud forms. However winter is good for convective clouds over the sea – as was evident in several pictures. However the forums have still achieved a good level of involvement and in a relatively short period, many interesting discussions and observations come up.” (Arcus)

Norte had daily participation in the ‘Identify the cloud’ topic. His extensive involvement allowed him to comment on the mission’s performance which he found to be engaging and successful. He also uses “we” when referred to the mission data connotation a community ownership feeling over investigations.

“There was an extended collaboration in the Spot-it mission where many of the members closely participated. We had many photos of clouds and I think that we succeeded in investigating most of the complex structures that one can spot in the highly variable cloud layer.” (Norte)

The same interviewee was also somewhat critical of the discussion topics, recognising a difference between several scientific fora and Weather-it community. He distinguished that Weather-it is more interested in collaborative investigations on topics relevant to the every-day life experience of science rather than battling over strong opinions.

“Unlike other scientific fora, where the topics usually end up in confrontations between everyone's strong opinions, this platform promotes the collaboration via data collection and sharing of ideas in topics that are not highly debatable but highly relevant to the society.” (Norte)

Benefits for scientists

Engagement with scientific investigations was one of the main benefits for the participants. However, one of the experts/interviewees acknowledged benefits for the experts and the

scientific community through Weather-it. Getting involved with non-experts and outreach activities provided scientists with the opportunity to articulate and review their knowledge.

“In the Weather-it community I had the chance to think and construct comments and answers that should be clear to the non-expert public. I can say that this also helped me to better conceive some notions about weather and the atmosphere. In my opinion, even in your area of study you don't know something if you cannot explain it to the others. In that sense, before Weather-it there were things that I only thought I knew.” (Norte)

Moreover, higher level of participation in the Weather-it community might also help scientists as well.

“If this is well-advertised and the participation is large it can be very useful to the scientists as well.” (Norte)

Suggestions

The interviewees were asked if there is something they would change to make Weather-it community more effective. Their suggestions focused on many aspects, including the number and type of forum topics, recruitment and type of members, and the technology used for the investigations. Arcus suggested that the number of forum topics should not increase so that topics will be easy to find. Moreover he suggested a discussion topic about weather predictions.

“I think it is developing fine at present. One point to watch (and from experiences with the TORRO members forum) is that the number of forums does not get too large. If there are too many, it may become less clear where to post items.” (Arcus)

“The Weather News sections can be very interesting. Perhaps another section could give a brief heads up on any significant weather predicted in the next few days.” (Arcus)

Norte was a member of the Weather-it community from the first day and thus he seemed to be more attached to the community. He provided suggestions – maybe desire – on how to maintain

the spirit of the community by sustaining the ratio between the expert and the non-expert members so that the latter won't be put off. Also, he advised that the platform will stay clear of advertisements and preserve its character.

"There are two suggestions from my side in maintaining this. One is to keep a low number of experts. A large number of experts would turn the discussions into scientific debates between them and this would drive the non-experts away. After all, one of the community's main causes is to engage the non-experts into exploring nature. A second suggestion is to keep the absence of advertisements (google ads, etc) that mess the image of the websites and overshadow their cause." (Norte)

Furthermore, Norte recommended the addition of more means of data collection for the inquiries such as weather stations and services.

"Maybe a suggestion is to promote the use of other means of data collection than the cell phones' limited sensors. There could be topics where the members are asked to find data and information in the numerous websites of weather stations and weather services. The data can be e.g. real time weather report from the various locations of the members, a weather map of an upcoming storm in one's location, possible record breaks in temperature or precipitation, information/photos on the aftermath of severe weather events, etc." (Norte)

This response corroborates much of the feedback on the nQuire toolkit inquiry tools provided by participants who took part in the questionnaire (Chapter 6.3.2)

6.5.9 Summary

The contribution behaviour of Weather-it members varied according mainly to their investigation preferences. Members may be interested in any available mission, in Weather-it missions, in a specific type of mission (Sense-it, Spot-it, Win-it) and in a particular mission. Although we can recognise the most popular missions, there is an interconnection between the mission

memberships and type of missions, which does not allow us to draw a pattern for co-joining missions and considering a specific type of mission as dominant.

The exemplar missions that were produced at the pre-birth stage of the community completed their inquiry circles by attracting participants and contribution, constituting the paradigm for the first members of the community. 'Record the sunlight' produced a comparative diagram with the average sunlight of each participating city during the recording period, 'Identify the cloud' attracted a number of individual picture inquiries and discussions, and 'Earth Vs Mars' received sufficient ideas and votes to announce a winning contributor.

'Air-pressure and rainfall' was the only Sense-it mission created by Weather-it members and received contributions by few participants as not many mobile devices supported a barometer. On the other hand, Spot-it missions were the most popular, gathering active participants, inquiries and discussions. Win-it missions were the easiest for members to create and received many ideas, with all but one of these missions being completed. However, the members who were posting ideas to Win-it missions tended not to inform the community about their methods and research process, leaving several inquiry phases set by the mission creator incomplete.

Further exploration of individual inquiries revealed the type of learning the Weather-it members were engaged in: content knowledge, annotation and identification skills and detecting and breaking down misconceptions. Furthermore, different behaviours were developed during their participation. A frequent behaviour is uncertainty when responding to a question or identifying an object. During their effort they sometimes demonstrate confidence, surprise and their perceptions on a phenomenon. In return they receive acknowledgement, rejection or no response.

Interaction between Weather-it members of different levels of expertise was one of the main aspects of the project. The interactions took place between and within expert and non-expert members. The emerging patterns of interaction were non-experts imitating experts, experts

providing information, both groups acknowledging each other, expert and non-experts mentoring non-experts and finally, experts and non-experts opposing experts.

There is no evidence of an ongoing vocabulary progress; however the dominant vocabulary of the last week articulates a roughly more scientifically spoken community.

Self-report on what Weather-it members learned during the participation in the project indicated 'knowledge about weather' first, followed by 'knowledge of new technologies' and familiarisation with the 'Citizen Inquiry' concept. There were also a few members that learned nothing and a member that became aware of her low self-esteem.

Experts indicated that the Weather-it project and similar projects have a potential to engage citizens with weather science and stated their satisfaction with the project design, interaction, participation, and inquiry levels. Several suggestions were provided for the enhancement of the community design and discussion topic whilst some benefits for the scientists were recognised, as part of their reflection on the project.

6.6 nQuire toolkit

Software is another central theme in this analysis as it accommodated the investigations and provided the inquiry and communication tools needed for the investigations and the collaboration between the members. The users' comments are separated in four sections. In the first section (Section 6.6.1) there are comments made during the project and retrieved from the forum log files. Some of those comments facilitated the ongoing software development and some others were added in the list with the future developments. The second section (Section 6.6.2) involves comments made in relation to the nQuire toolkit usability at the end of the project and retrieved from the survey responses. The third section (Section 6.6.3) outlines the members' suggestions on the software improvement. The fourth section (Section 6.6.4) demonstrates comments that reveal the software's novel aspect. The data from the log files, the questionnaires and the

interviews have been subjected to a thematic analysis using the approach of Braun and Clarke (2008) which was outlined in the Research Methods chapter (Section 3.4.3).

Finally, the last section lists the developments to the nQuire toolkit after the end of the project.

6.6.1 Forum Comments

At the start of Weather-it project some forum threads were created in order to provide members and other users a place for their feedback (Figure 84):

Forum • Bugs, feedback and suggestions				
Post new thread				
Thread	Starter	Last post	Replies	
App bugs	rhian	sharplem 14/5/15 8:11 AM	9	
Report a bug	Maria	rizzi.cristian 9/5/15 5:29 AM	13	
Suggestions	Maria	nikola.milicic 26/1/15 1:26 PM	14	
Request: Allow to input raw data through sense it app	p3tris	sharplem 11/12/14 9:31 PM	3	
Bug with extende ASCII characters	crizzi-arg	sharplem 18/11/14 11:05 AM	1	
Translation into other languages (e.g Spanish)	crizzi-arg	crizzi-arg 15/11/14 11:59 AM	6	
Welcome!	admin	admin 7/7/14 3:57 PM	0	

Figure 84: Bugs, feedback and suggestions forum

6.6.1.1 Suggestions

The main theme that emerged from the suggestions forum thread during the project was the notification system and its improvement. Other themes included log-in, social technologies and investigation issues.

Notifications: The most frequent request coming from the Weather-it participants was the establishment of a notification system that would notify them about tasks and activities:

“It would be great if I could receive a notification when somebody else posted a comment in a forum where I participated (and maybe when I get a like :). Also a daily/weekly digest with updates from the forum, new missions, new data, etc. would be useful (it would be a good way to keep track of what is happening and a reminder to post my own updates).” (Bora)

“As a user I would like to get notification when I should do a mission task. For instance, for the project 'Record the Sunlight' the task need to be performed every day at 13 CET. I would like to get a reminder (app notification) from the app a couple of minutes before that.” (Nashi)

“Hi. I agree with some of the other people above about notifications. I would like to be able get notifications when someone replies to one of my comments. Or at least to be able to login and then find a link to all my new comments.” (Williwaw)

The above requests focus on facilitating their interaction with the community and the project. Thus, there are suggestions in relation to getting notified when someone replies to their posts and when it is time for a mission task. There are also appeals for having direct access to all of their personal posts so that they will be able to review the updates themselves. Moreover, there is a request for having frequent updates with news from the community. The moderator took into consideration the above suggestions and proceeded to adopt a manual notifications technique (Chapter 5.3). Thereafter, the members were sent manual notifications when they had replies to their posts and a weekly update email with the news of the community.

Login: There were also suggestions that the **login system** could be improved:

“Please make sign-in sessions longer. If you're writing a long comment you'd probably have to copy and paste it after you have signed in again..!” (Diablo)

“It would be nice if one can login sense-it app with an account different to @gmail... otherwise ppl have to use two accounts in order to participate if they have not registered here with gmail...” (Leste)

The first comment focuses on the duration of the session time which seemed to bother others users as well who were trying to post big messages. The latter comment refers to the Sense-it login which can only be made with a Google account. However, the particular user has been informed that she can merge her Sense-it and nQuire-it accounts on her profile page.

Social technologies: Weather-it members were also interested in improving the social technologies within the community.

"In the 'Identify the cloud' mission: when you're actually looking at a photo, you can't see the name of the person who uploaded it. You can on the main page, but not once you click on the photo to view it full screen." (Ostria)

"Suggestion: the option to reply to a specific post in a thread, rather than just add a comment onto the bottom of the list. Would make it easier to follow multiple specific conversations that end up taking place within the same general thread." (Ostria)

"[...] I can't add pictures to the forum without having a link to that picture somewhere else. If I take my own picture I have no way to post it." (Williwaw)

The first comment refers to the improvement of the picture view and the second to the enhancement of the communication by enabling users to respond to a specific comment instead of adding a generic comment. The last comment refers to the improvement of picture attachment to the text on the forum which is not currently available.

Investigations: A member suggested an additional feature to Sense-it that would provide another method for collecting data:

"Is it possible to allow for raw data to be send for a mission? For example, I have a thermometer at my house and I'd like to create a mission to measure temperature and keep history. My cheap android phone doesn't have a temperature sensor... It would be really useful if I could send the data to the mission through the app!" (Zephyros)

User-entered data was not a possible thing to implement during the project but it was kept in mind as one of the future features as it is a useful and flexible method for collecting data that will be easy to process later.

6.6.1.2 Bugs

The bugs mentioned by the Weather-it users on the forum thread concerned the Sense-it application:

"The 'About Sense-it' option doesn't do anything." (Ostria)

"I tried to upload yesterday's light record and when I pushed on the app the cloud icon, it directed me to a link on chrome and it stuck...when I refreshed the page, the data was neither visible here on the platform nor "upload-able" on the app itself. Any suggestions?" (Levanto)

"[...] So I suggest that if possible, the date of recording is taken into account, and not the date of pushing the data to the server." (Nashi)

The first two comments refer to bugs in relation to the 'about' and 'upload' button that were fixed after mentioned. The third comment suggests a change on the date of the data when uploaded to the server as the current system may interfere with the validity of the results. This has not been yet implemented.

6.6.2 Usability

In order to evaluate the usability of nQuire toolkit, the Weather-it members completed a usability Likert Scale (Figure 85), as described in Section 3.4.2.

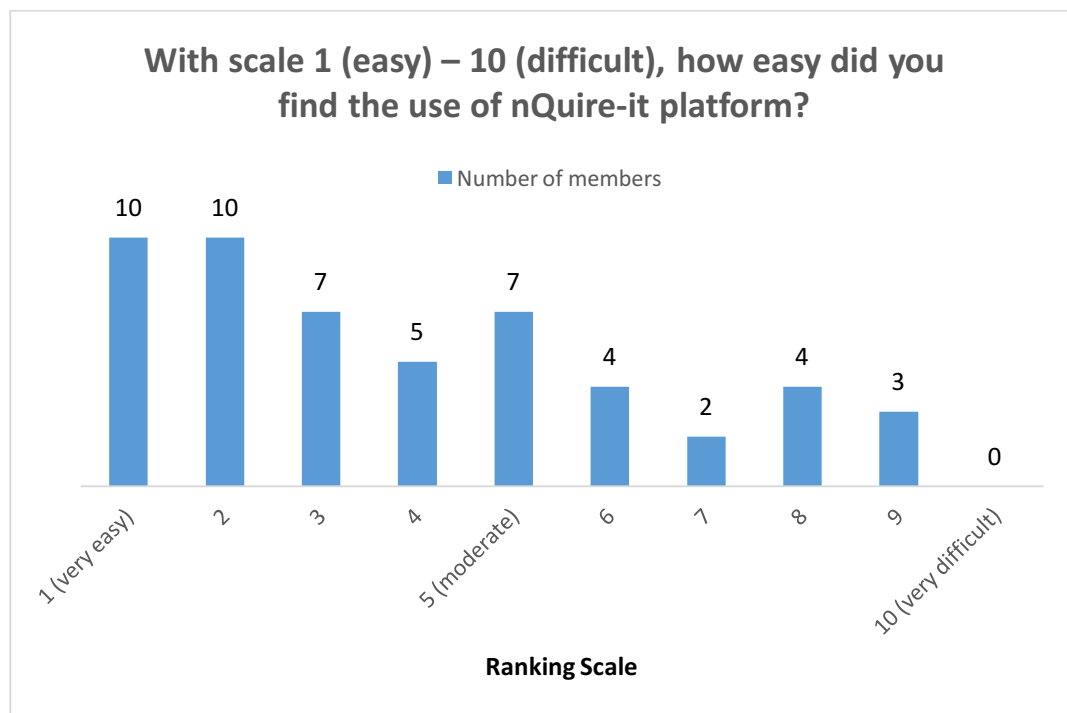


Figure 85: Usability scale

The results (n=52) showed that most Weather-it members find the platform ‘moderate to easy’ to use, with the sample mean equal to 3.90 out of 10. The scale was followed by comments which are outlined in the following sections. The comments were retrieved by Questionnaire B (n=61) and interview questions (n=7) that had to do with their satisfaction with the software usability or emerged from questions in relation to the reasons that some members got engaged/disengaged from the community.

The survey responses included both positive and negative comments regarding the usability of nQuire toolkit. Some members seemed to be very satisfied with the nQuire-it structure and browsing and found it easy to use. For example:

“The platform is easy to use and the ideas are described well, in a simple way so it's easy to follow.” (Bora)

“Well organised platform and project.” (Norte)

“It was very easy to create the mission and maintain it until the voting stage. The platform is very well structured and everything was clear.” (Norte)

"Easy way to browse through its options and subjects." (Levanto)

Some of the members found it difficult to use nQuire-it platform because of its design. There were difficulties on where to start from and how to browse things as well as feedback on the login and forum and inquiry technologies:

"I found the website quite complicated to use and I wasn't really sure where to start." (Gregale)

"I had some issues sometimes with logging in so I mostly used it from my phone and had to always log in every time I visited the site." (Levanto)

"I think I was confused by the variety of colours and lines and designs...I do not know how to explain...I am like a dyslexic person that gets confused with multiple things. However, I had immediate instructions when I asked for help." (Typhoon)

"The forum way might look kinda boring especially if you need to look up for something quickly."
(Levanto)

"I was a bit confused when trying to upload pictures because I thought that as I'm a member I can do so in every mission. I didn't know that I needed to join each mission separately. That was the only confusing part." (Funnel)

However, the Sense-it application seemed to be the most difficult to use as although some members wanted to use it they could not figure out what each sensor measures and how they can use them for their investigations:

"I wanted to use some of the phone sensors but it was hard to work out what lots of them did/do."
(Williwaw)

"Another reason might be that although I discovered thanks to sense-it that my phone has many sensors I could use for the missions, I wasn't quite sure how and what exactly do some of the sensors measure and how could this be used in relation to detecting weather changes etc." (Bora)

The above comments may have suggested the creation of a tutorial embedded in Sense-it application for the use of the application and for each sensor individually. As a result, Sense-it has now included help information about each sensor.

6.6.3 Suggestions

This section demonstrates the emerging themes from the survey data (n=61) in relation to the suggestions on the nQuire-it platform and Sense-it application. Those are related to the user interface, the inquiry and communication tools and the mobile features:

6.6.3.1 User Interface

User interface theme includes all the suggestions that have to do with the front end design and how the members interacted with the technologies. Thus, there were suggestions for adding language options for the non-English speaking people, make the instructions more visual for beginners to understand and make experts more identifiable on the platform for the non-experts to find:

“Selection in languages.” (Brubu)

“The forum is kind of hidden there.” (Mammatus)

“Short descriptions, using bold font, other colours, visual reading for the instructions!!” (Mistral)

“Make it more user friendly by adding more user experience features (making it easier for a complete amateur to post or contribute).” (Sumatra)

“Recognise who is expert so I can bother them :)” (Stratus)

6.6.3.2 Inquiry tools

Some other suggestions were related to the investigations and the enhancement of the inquiry tools and process. Members were interested in being able to contribute without joining a mission, making more mission types available, and providing tools for on-platform data collection and analysis:

"I don't like the fact that I have to join a mission in order to type. I would understand that if I could see the other members of the mission and chat with them. I don't find reason of its existence if the members are invisible." (Mammatus)

"I would like to see more types of missions (e.g. polls, etc.) and more tools for data analysis. People post on that platform their raw results. It would be nice if weather data analysis tools were embedded in the missions." (Euros)

"I'd like to add video/photos to comment post (like on Facebook)" (Williwaw)

"I would like to be able to analyze my responses on the platform, especially to organize them in categories, add tags on them, etc. For example the 'identify the cloud pictures', the collected data would be more useful if you could separate it into types of clouds with tags or in some other way." (Cumulus)

6.6.3.3 Communication tools

The majority of the suggestions were regarding the communication aspect of the community. People who have left the community in an early stage before the "manual notifications" era mentioned notifications as their first suggestion. For instance:

"I have written the suggestion on Notifications in the forum page as well but I think it's important to keep me alarmed when somebody may answer to my posts or comments." (Austru)

Some other members stated that they would like to have the notifications on-platform instead of getting them to their emails:

"I would like notifications on the platform, I don't like having emails all the time." (Undulatus)

Suggestions on enhancing the communication between the participants were frequent, asking for personal messaging features or making friends so that they maintain a more private communication with other members of the community:

"I would like to message people on the platform or have friends." (Stratus)

"As a community is fine but what about communication between the members? I cannot see who liked what, who attended what, I can't speak to other people." (Mammatus)

Finally, there is a comment suggesting tag features in the comments, so that the members will be able to address a comment to a specific member that in turn will get a notification about it and revisit the post:

"Make it easier for people to interact with one another. For example, if someone posts a comment, it would be nice for me to be able to write their name and then they get a notification to say that I have written in reply to them or written their name. There were a few attempts to do this by people from what I saw but I don't think that those attempts were always successful because people had to go back to the exact same page and check up on it." (Williwaw)

6.6.3.4 Mobile features

Members who are more interested in the mobile technology had suggestions in relation to the enhanced use of mobile devices in the project. For instance:

"Facebook login for Sense-it." (Sundowner)

This member requested an option to login to Sense-it with a Facebook account. The current application allows only Google account holders to login. Another comment suggested that Spot-it missions should be linked with an application similar to Sense-it which will upload directly the pictures onto the mission along with their geo-tagging information:

"Maybe the option to upload photos snapped with a mobile phone directly to a spot-it mission (including geo-tagging information)." (Zephyros)

A Spot-it mobile application is already on a list of future developments as it will facilitate better data collection and analysis, but has not yet been implemented.

6.6.4 Novelty

Beyond the comments on the usability of the nQuire toolkit and the suggestions for improving it, there were some responses that highlight the novelty of the software and in particular Sense-it Android app. Some members use the Sense-it app for tasks that are not related to Weather-it:

“Firstly I was very pleasantly surprised about the sense-it application used for the experiments. I had no clue the little device in my pocket had so many sensors (I had an idea about some, but not all) and that the output of the sensors could be so easily recorded. Although I am not active in the online community during the past weeks, I keep using the mobile application for things of my own.” (Bora)

There were also responses revealing members’ surprise about the use and importance of mobile phones in investigations. For instance:

“I haven't thought of using my phone sensors in those interesting ways.” (Leste)

“It is possible to explore with simple technology we already have such as the sensors on our phones!” (Williwaw)

6.6.5 Sense-it calibration

This section presents a technical evaluation of the Sense-it app based on the measurements of the ‘Record the sunlight’ mission. The analysis involved sunlight measurements in the same area and date/time of (a) different mobile devices (Table 31 and Table 32) and (b) same mobile devices (Table 33 and Table 34). The percentage difference (C) of each pair of measurements (A and B) was calculated by finding the difference between the two values, then dividing the result by the absolute value of A and multiplying the result by 100. i.e. $C = [(A-B)/|A|] \times 100\%$

Table 31: Comparison of light measurements at the same time and location – Moto G (I) and Nexus 4 (I)

Date	Moto G (I) (Lux)	Nexus 4 (I) (Lux)	Percentage difference
23/11/2014	1752.2727	1596.0646	9%
24/11/2014	4113.0713	2244.2258	45%
25/11/2014	3996.5715	2282.7585	43%
27/11/2014	4890.483	3359.6775	31%

Table 32: Comparison of light measurements at the same time and location – Moto G (I) and Nexus 4 (II)

Date	Moto G (I) (Lux)	Nexus 4 (II) (Lux)	Percentage Difference
11/12/2014	5117.3076	1322.4814	74%
12/12/2014	5515.9116	1423.8214	74%
17/12/2014	2509.2334	1133.7812	55%
18/12/2014	4016.724	3785.3667	6%

The findings from the comparative analysis among Moto G and Nexus 4 (I) resulted to an average percentage difference of 32% with a standard deviation of 14%. The comparison of Moto G with the second Nexus 4 device resulted to an even a higher average percentage difference (52%) with a higher standard deviation (28%), although the two Nexus devices have the same sensors (LGE Light Sensor).

Table 33: Comparison of light measurements at the same time and location – LG G2 (I) and LG G2 (II)

Date	LG G2 (I) (Lux)	LG G2 (II) (Lux)	Percentage Difference
2/12/2014	1259.16	580.7241	117%
5/12/2014	6313.32	3850.643	64%
7/12/2014	4180.64	4741	13%
9/12/2014	2434.72	3556.5	46%
10/12/2014	672	1487.7858	121%
13/12/2014	3786.4	2826.074	25%
15/12/2014	1747.56	2043.6786	14%

Table 34: Comparison of light measurements at the same time and location – Moto G (I) and Moto G (II)

Date	Moto G (I) (Lux)	Moto G (II) (Lux)	Percentage Difference
18/12/2014	3785.367	3268.441	14%
19/12/2014	2547.08	3340.946	31%

The first comparative analysis between mobile devices of the same brand (Table 33) gave even less expected findings, as the average percentage difference was as high as 57% with a high range in sunlight measurements (SD = 42%). The second comparison (Table 34) consisted of only two pairs of measurements and gave better results with lower average percentage difference (22%) and standard deviation (12%), and thus the measurements between the two devices did not differ as much as in the first pair.

However, the high and not consistent percentage differences between the pairs in all four cases raises concerns about the validity of the Sense-it investigations and do not help in scaling the sensors of these devices as was discussed in Section 5.3.4.

6.6.6 Developments to nQuire-it and Sense-it

With the feedback that Weather-it members provided, a number of major developments were implemented by the nQuire-it development team, after the end of the project:

- The Sense-it app was enriched with help information about each sensor so that the users know what each sensor does and how it can be used.
- Language option was installed on nQuire-it platform, for Greek and Spanish, with an option for adding other languages.
- Automatic notification system was implemented, which sends notifications to the user's email address. The users can select, from their profiles, in which cases they want to receive notifications: posts/comments to a mission or forum they created/commented on.

6.7 Summary

The nQuire toolkit (nQuire-it platform and Sense-it Android app) went through some formative and summative evaluation. The nQuire-it forum that accommodated comments regarding the software provided some ongoing evaluation of nQuire-it and Sense-it app that helped in the improvement during the Weather-it project duration. The forum included mainly suggestions and a bugs thread. Suggestions were related to the activation of notifications, the login duration increase, and the addition of more social technologies to the platform and data collection methods to the Sense-it app. Comments in relation to bugs focused on the Sense-it app, referring mainly to issues such as buttons that do not work. A number of these issues was resolved during the project.

Part of the summative software evaluation was a usability Likert question. The result showed that Weather-it members found the nQuire toolkit 'moderate to easy' to use with score of 3.9 – where

1 is equal to very easy and 10 is equal to very difficult. Comments by people who considered nQuire toolkit easy to use include the well organised platform structure and the easy to start and maintain missions. Members who found the software difficult to use, mentioned such reasons as the overly colourful interface and the cumbersome forum. However, Sense-it seemed to be the most difficult to use as several members did not get round to using it and could not understand what each sensor does.

Suggestions in relation to the improvement of the nQuire toolkit involve aspects of the user interface (e.g. more languages), the addition of more inquiry tools and investigation options (e.g. data analysis features) and the enhancement of participation with more communication tools (e.g. friends, personal messages). Moreover, some of the suggestions focused on enhancements that will allow more use of the mobile phone (e.g. Spot-it application).

Comments highlighting the software novelty were mainly focused on the Sense-it app. Some members used it for tasks outside Weather-it project, showing their surprise about the potential capabilities of their mobile device and how simple technology may help investigations.

Finally, the findings from the comparative analysis of Sense-it sunlight measures among different and same mobile devices in the same area and date/time exposed validity issues in relation to the investigation results. Furthermore, the inconsistency between the percentage differences makes the efforts for scaling the sensors and improving the calibration more complicated. Weather-it results are further discussed in the next chapter.

Chapter 7: Discussion – Designing for Citizen Inquiry and other Citizen Participation Communities

7.1 Introduction

This chapter will integrate and discuss the findings of the four aspects that surround the Weather-it project (creation and sustainability in online community, engagement, inquiry, and software) and the Inquiring Rock Hunters project (inquiry, collaboration, mentoring, and software). The findings will be explained and considered within the context of a comparative analysis between these two design studies and against other previous research on citizen participation projects and online communities. Each of the three research questions will be considered in turn, with the emphasis on exploring evidence across the two design studies. Thereafter, there will be a reflection on the researcher's presence within the environment and a list with design considerations for the creation of future Citizen Inquiry and other citizen participation communities. The chapter will conclude with a discussion on the scalability of Citizen Inquiry projects and the applicability of the design considerations.

7.2 How can we create an active and sustainable online community for Citizen Inquiry? (RQ1)

For the recruitment and sustaining of members, Citizen Inquiry projects should take account of recent literature on aspects of online communities and design principles. Members may initially be attracted to the community for diverse reasons (personal educational goals, entertainment, collective scientific goals etc.) (Curtis, 2015). According to research on design principles for citizen science, platform design principles should go beyond the standard usability considerations, and

consider how to motivate members to join the community initially (Wald, Longo & Dobell, 2015).

Therefore, the findings will be discussed in terms of recruitment and motivation factors.

7.2.1 Word-of-mouth as the most powerful means of recruitment

The findings regarding the participants joining the community are aligned to studies that suggest word-of-mouth as the most powerful advertisement (Trusov, Bucklin & Pauwels, 2009). The word-of-mouth recruitment of Weather-it members seems to be the most effective means of inviting people (46% learned about Weather-it from friends/colleagues) although it is not clear whether word-of-mouth took place face-to-face or by electronic means. An explanation for the high percentage of word-of-mouth recruitment may be that mission and data owners in Weather-it project are the source of the 'news', as research on word-of-mouth highlights the role of 'self-involvement' as a key motivation that drives individuals to engage in word-of-mouth behaviour (Dichter, 1966). In self-involvement members want to share their knowledge or opinion (i.e. mission and data) as a way to gain attention and feel like pioneers. Another motive which is mentioned in research on online marketing communities is 'help to company' (Sundaram, Mitra & Webster, 1998) which in Weather-it may have worked as 'help to community' as many of the participants joined the project "because of the community" (Section 6.3.2) and 68% of the survey respondents (36) mentioned that along the way they felt like a part of it (Section 6.3.7). This 'emotionality' (Berger, 2014) to the community indicates why existing members may have invited new members to the community.

Indirect recruitment through mailing lists and social networks was effective for attracting people who had no connections with the community, and thus had little prior knowledge of the community. Although the advertisement of the community targeted mostly citizen science, weather societies, and modules related to weather, only a small proportion (13%) of the members heard about Weather-it from there. Advertisements on blogs and social networking sites were used as means for people to interact and exchange information about the community. However, it has been noticed from the survey responses that they were not very popular (Section 6.3.1) and the blog leaflets did not spark discussion to a great extent.

Moreover, none of the participants was recruited from the paper leaflets. An unexpected finding was also linked to the “searching the internet” answer, as one member joined the community with no invitation or information about it. One way of improving members’ recruitment to Citizen Inquiry communities, apart from relating to their motivation for participating, may be to positively enhance the word-of-mouth behaviour. Research on word-of-mouth outlines reasons that drive what people share and suggests that people tend to share more entertaining, accessible, unique, common ground or useful information, high status goods, emotional valence and identity-relevant things, etc. (Berger, 2014). Thus, the design and promotion of Citizen Inquiry communities should also focus on conveying these characteristics; for example by highlighting the useful science information you may receive in an entertaining way.

7.2.2 Personal benefit as initial motivation for participating in Citizen Inquiry

Since Weather-it had no specific scientific goals other than the involvement of the members in weather investigations and discussions, the motivations for participating in the community differ from other citizen participation projects.

Comparing the results with a research study on motivations that initiate participation in citizen science projects (Curtis, 2015), some main differences were spotted. Whereas in some citizen science projects the main reasons for participating is the contribution to research and the interest in science (Raddick et al., 2010; Nov, Arazy & Anderson, 2011; Curtis, 2015), Weather-it members ranked ‘weather’ as their first reason (interest and learning about the topic). Contributing to science and scientific interest ranked last, after the social-related reasons (friends and community), and the interest in the software (Section 6.3.2). ‘Community’ and ‘astronomy’ were also highly mentioned in astronomy citizen science projects (Raddick, Bracey & Gay, 2010; Raddick et al., 2013) but ‘friends’ and ‘software’ not to such a great extent.

‘Friends’ as a motivation to join the community may also explain the popularity of ‘word-of-mouth’ as a means of recruitment, as research has shown that common ground between the word-of-mouth sender and receiver enhances its influence (Berger, 2014; Sweeney, Soutar &

Mazzarol, 2014). It is also notable that all the members whose only motivation for participating was community and friends (n=15) remained active until the end of the project, in contrast to those (n=16) whose only motivation was the topic; half of them dropped out [Questionnaire B].

The motivations in Weather-it did not differ much from the 'Inquiring Rock Hunters' study, as the majority of rock hunters (60%) joined the project stimulated by personal incentives (interest in the topic, learning, etc.) and only 17% were sparked by social incentives (contribution, etc.) (Section 4.8.1). As expected, "goals of the project" was not a part of the reasons that led them to join the communities, as both had no specific goals linked to a single science research project.

A reason for the difference between the motivations for initiating participation in citizen science versus Citizen Inquiry might also lie in the nature of nQuire-it missions. A potential interpretation of participation in Weather-it is that the participants got involved in everyday life topics, without labelling them as science. Part of the reason for this behaviour might be the background of the participants, as very few were meteorology scientists or associated with weather or a related field in a professional capacity. Weather-it attracted many members who were beginners and had neither weather experience nor a science background (Section 6.3.3). The experts joined the project mainly for the topic, beginner and intermediate members also ranked 'friends' and 'community' motivations at a higher level. Thus, there are individuals that bring some expertise to the project and beginners who want to learn more about the topic along with their friends in a community offered as a learning experience.

Another aspect that may influence motivation for initiating participation in Citizen Inquiry is the type of recruitment used. Lessons from previous research (Ren & Kraut, 2013) showed that for improving the success of a community decisions for designing it should not be taken through trial and error but guided by member motivation and contribution. Thereby, since personal interest and benefit constitute main reasons for joining some citizen participation projects, such as Weather-it (Section 6.3.2), Inquiring Rock Hunters (Section 4.8.1), and Planet Hunters (Curtis, 2015), recruitment should focus on those incentives. In this regard, research on citizen science

also proposes that recruitment should emphasize aspects of the project that fulfil those personal needs (Rotman et al., 2012), such as more educational materials (Raddick et al., 2010) and simple tools for interaction or data manipulation (Bonney et al., 2009). In Weather-it community members were requesting information from other members about educational materials related to their inquiry and they were sharing the ones they have found (e.g. list of cloud types) (Section 6.5.5.2).

An aspect that facilitated the recruitment of new people to the community was the opportunity that nQuire-it platform provides for multiple ways to participate (types of missions) (Section 6.4.4.1), which according to Bonney et al. (2015) acknowledges different interests and motivations and leads to larger audiences. Advertisement leaflets for Weather-it (Appendix O) and Inquiring Rock Hunters (Appendix I) laid emphasis on the tasks, the activities, and the collaboration within the projects, without emphasising any contribution to science. As was expected for a more learning-oriented citizen participation project, few members interested in contributing to science were attracted. Furthermore, although experts in Inquiring Rock Hunters project were invited separately, Weather-it did not focus on incentives that would attract experts and determine their role in the project. As a result, some beginner rock hunters expected an expert to be assigned to them (Section 4.8.2) and experts in turn adopted the role of the facilitator in investigations and discussion forums (Section 4.8.4). In contrast, non-expert Weather-it members did not say they had any high expectations of the experts and the experts had broader participation behaviour. Citizen participation projects like Citizen Inquiry, however, may not attract experts, if their main motivations for participating are co-authorship, presentation at conferences, etc. This suggests further research should be paid to how to attract and engage experts in Citizen Inquiry projects.

7.2.3 Project communication and community identification for retention

Findings from this thesis suggest that the evolution of the community depends mainly on the project's communication pattern – the advertisement, the notifications, the daily/weekly updates, and the personalised messages to the participants. Of equal importance is the behaviour of some

members, such as the core group and the experts, whose contributions provide a spark of interest for other members. Having established the nature of the community and Citizen Inquiry, the members gradually develop a common scientific vocabulary (Section 6.5.6), try to recognise who the experts are through their interaction with them and they get to share more useful ideas and data (Section 6.5.5).

The period between the second and third evolution stage, at which email notifications and weekly updates began, generated further interactions between more members. Personalised communication with non-active members, alongside frequent communication with the entire community, led to the fourth stage of the community evolution where there was a 40% increase in the interactions in three weeks. Furthermore, the last six weeks found the community at a 'maturing' stage with steady fluctuations (Section 6.3.5).

The Weather-it results indicate that the community sustainability relies in part on the ongoing support of the community e-moderators (Section 6.3.6 and Section 6.4.6). Results of the Snapshot Serengeti project have also demonstrated high participation level, mainly due to the high levels of blogging by moderators (Cox et al., 2015). These findings support conclusions of previous research that identifies that the initial design of the early first stage of the community development is inadequate to make the community "run itself" (Stuckey & Smith, 2004). Alternatively, the ongoing design and development during the growth of the community, as applied to Weather-it, should depend on the individual community and its needs (Engeström, Engeström & Suntio, 2002; Fischer, 2002). It is also aligned with findings from citizen science communities that indicate regular contact by project leaders as the main factor that supported retention of members (Wald et al., 2015). Further evidence supporting the essential role of the e-moderator and the facilitation of the community lies in the findings of level of participation after the end of the project. The analysis indicated gradual decrease of contributions which finally reached the bottom seven weeks after the facilitation ended (Section 6.4.6). Therefore, a conclusion may be that a single moderator is not sufficient for sustaining participation in the community. Moderators need to be identified, for instance between the weather enthusiasts, and form a core of facilitators.

Another solution is the creation of automated features for moderating the community (e.g. recommendations, reminders, organisers).

Feeling a part of Weather-it reflects the commitment to the community (Meyer & Allen, 1991) and thus predicts whether members will be retained in the future. Although the majority of Weather-it members felt like a part of the community, an important percentage (32%) did not (Section 6.3.7). Surprisingly, almost half of those are members with many contributions to the community. The reasons for not feeling a part of the community might be explained by a) the absence of opportunities for bond-based commitment (members closer to other members) as the project was mission-centric, b) homogeneity issues (different age), c) frequency of visits, and d) their newcomer status.

Another potential reason may be the lack of a shared purpose, as Weather-it employed many investigations each with their own goals. This may affect the identity-based commitment of the members, as there is no sense of a common enterprise from which they will benefit (Michinov, 2004). Findings in this work show that contribution to the community is not necessarily linked to feeling like a part of it. However, similarly to research on students' retention to online learning environments (Boston et al., 2014), when members feel like a part of a larger community they are more likely to have increased retention. Future research needs to focus on how to eliminate reasons that may prevent members from identifying themselves with the community.

7.2.4 Platform design for sustaining engagement

The majority of the Weather-it members referred to the software either as the reason they liked the project and thus remained engaged, or as the cause for not being active at the time of the survey. In *Inquiring Rock Hunters* (Aristeidou, Scanlon & Sharples, 2014b), most of the members commented on the difficulty they would have had to use nQuire platform without a tutorial, but also showed their satisfaction with the existence of some tools, such as the inquiry diagram. However, their suggestions for improving the platform were restricted mainly to the addition of communication tools, such as chat, video teleconference and improvement of the forum,

emphasizing the importance of interaction within the community. Weather-it members were more satisfied with the software usability, without using a tutorial, but still had many suggestions on how to improve the software.

The nQuire-it platform was generally found to be easy to use, with some Weather-it members commenting on the well organised structure, the ease of browsing subjects and creating missions (Section 6.6.2). Also, in contrast to the investigations in Inquiring Rock Hunters, Weather-it missions were visible on the platform, allowing members easy access and re-visit of the investigations, supporting follow-up discussions. However, several members spotted software bugs or limitations during or at the end of the project (Section 6.6.1 and Section 6.6.3). The feedback allowed some ongoing improvements and the creation of a list with further design requirements, related to the user interface, project communication, social and inquiry technologies. Further issues were identified through tests by technology and human computer interaction experts during the platform preparation. These were not realised due to lack of time, but if they had been, may have prevented some drop outs from members who found the software complicated (Section 6.6.2). One specific technical issue was the nQuire-it site not coming back online after a server reboot a few days before the launch of the project, while recruiting participants and having the core-group members on the platform. Moreover, the login via social networks went off after automatic updates to the Java virtual machine. Some other issues had to do with technology restrictions. For example, there was no 'Forgotten my password' button, the duration of the login sessions was short but the front-end was still showing users as logged in, there was no 'edit' button in the comments and forum posts, and numbering and bulleting in the text processor was buggy.

Project communication was one of the main factors that supported the retention of members in the community (Aristeidou, Scanlon & Sharples, 2015b). The project communication, however, may be enhanced by software features that facilitate the moderators in their efforts to maintain communication with the community members. 'Notifications' is a feature that supports participation in the community (Kraut & Resnick, 2011) and was also a frequent request by

Weather-it members (Section 6.6.3). Some members of Inquiring Rock Hunters asked for a list of unread forum messages. In Weather-it, suggestions during the first weeks of the project and by members who left the community before the 'manual email notifications technique' based on Wizard of Oz paradigm (Section 5.5.4) had been set up, requested notifications to inform them about any responses to their posts. Other requests involved platform instead of email notifications and task reminders. Last but not least, was the establishment of a daily/weekly digest with community updates (Section 5.5.5), which as stated helped some members feel like part of the community (Section 6.3.5).

Feeling like a part of the community can also be supported by enhancing social presence in the community, as it helps to perceive other members as "real people" and describe themselves socially and emotionally (Swan & Shih, 2005). It is also important for satisfactory and meaningful collaborative online learning and inquiry (Richardson & Swan, 2003; Akyol et al., 2009; Shea & Bidjerano, 2009). Communities in Inquiring Rock Hunters and Weather-it provided social interaction through the open communication in forum topics, and group cohesion in collaborative investigations. In Inquiring Rock Hunters, the synchronous chat was found to be inefficient due to the small number of participants and thus members asked for personal messages. Likewise in Weather-it, although members had personal profiles with information about themselves, there were limited communication options between the members. Feedback on the community and platform design (Section 6.6.3.3) suggested the need for a more enriched interactive environment with an increased sense of co-presence. Their suggestions focused on being able in the environment to have friends and communicate with them directly with personal messages or tag them in a comment. They were also interested in what other people in the community were engaged with.

Platform design should also involve a thorough investigation of the inquiry and specialised tools that the community should offer to its members. Rock hunters had suggested the integration of geology-related tools such as microscope, rock identification key and a guide for beginner rock hunters (Section 4.8.5). Suggestions by Weather-it members focused on the inquiry tools they

wanted to have available for their data collection, manipulation and analysis (Section 6.6.3.2). Concerning the project design of a citizen participation project, research indicates that more time should be allocated for the alignment between the project formation and objectives (Druschke & Seltzer, 2012; Bonney et al., 2015). Similarly, in the Citizen Inquiry communities, members were encouraged to get engaged more fully in the research process; thus, there is a need for more user-oriented research tools related to inquiry and field observation, to support engagement.

7.3 How can Citizen Inquiry engage members of the general public with investigations? (RQ2)

Several techniques were employed while preparing the Citizen Inquiry community and throughout the project in order to enhance members' engagement (Sections 5.3 – 5.5). As a result, and as in other citizen participation projects, some members were engaged more, some less and some abandoned the community.

7.3.1 Engagement in all aspects of the scientific process for longer participation

It is argued by the Committee on Science Learning (2007) that with a greater degree of participation, members are more likely to increase their science identity and thus internalise science learning more easily. Furthermore, a review by Bonney et al. (2009) on different models of public participation demonstrated that the more the individuals are involved with all the aspects of the scientific process, the more likely they will increase learning outcomes. The Weather-it community which involved members more in the inquiry phases, by comparison to contributory citizen science projects, managed to sustain members' participation in the community for a longer time with roughly periodic visits (Section 6.4.1). The findings have shown that Weather-it members' relative activity duration (mean = 0.43) was higher than Milky Way's (mean = 0.20) and Galaxy Zoo's (mean = 0.23).

7.3.2 Engagement profiles for behaviour detection

The key objective of mapping the behaviour of the community members is to detect the desirable and non-desirable community behaviours and how these were prompted. In addition, it is important to understand how the causes of those behaviours can be enhanced or eliminated.

Ponciano and Brasileiro (2015) found five engagement profiles within their data of Milky Way and Galaxy Zoo projects: 'hardworking', 'spasmodic', 'persistent', 'lasting' and 'moderate'. These categories were identified after clustering engagement metrics that placed emphasis on the degree and duration of engagement. In Weather-it, the daily devoted time has not been included and a lurking metric was added (Section 3.6.4.2). As the results of this study showed (Section 6.4.2), 'hardworking' (7%) and 'persistent' (19%) engagement profiles have been found, but the other profiles were not spotted within the Weather-it dataset. Instead, new engagement profiles emerged to describe the participation main behaviour of members in Weather-it; 'loyal' (13%), 'lurking' (7%) and 'visitors' (55%). The 'loyal' category captures the long stay of some members in the project, as does the 'persistent' one, but also combines higher levels of activity, as in the 'hardworking' one. Hence, 'loyal' exhibits a desired engagement profile in which volunteers remain both linked in and active in the project. The 'lurking' category may also be related to the 'persistent' but it is distinguished due to the relatively high lurking levels. Therefore, members of this engagement profile remain linked to the project but they are mainly observers. The last category, 'visitors', was created in order to gain some insight into the profiles of people who had two or fewer active days in the project, and draw some conclusions in relation to the attrition rates within the project. The findings suggest a variety of behaviours, as some are hesitant visitors with the prospect of moving on eventually to another category, and some others are more active or lurking visitors.

7.3.3 Motivations for sustaining participation

Survey results have also enriched the engagement profiles providing information about the motivations for initiating participation in the project (Section 6.4.2). Understanding those

motivations is important for sustaining participation (Wiggins & Crowston, 2010; Nov et al., 2011; Romeo & Blaser, 2011).

'Weather' is the first motive in all the categories apart from 'persistent' in which members have more social motives to participate, such as 'friends' and 'community', placing 'weather' third. Moreover, 'hardworking' was the only category mentioning 'software' as many times as 'weather'. From these findings there is a suggestion that interest in the software may bring in more active volunteers, but for a short period, whilst motivation by friends within the community may cause longer stay in the community. The latter may have happened because of existing ties, people who are already friends with the volunteers, who have joined the project enhancing the bond-based commitment to the project (Ren & Kraut, 2012). This 'social' aspect has also been encountered as the strongest motivation of gamers who had persistent participation and they were very committed in the game (Herodotou, Winters & Kambouri, 2012).

On the other hand, loyal volunteers, who were both active and linked for a long time to the project, did not choose 'friends' to such a great extent as the other categories. It seems that the volunteers of this category are attached to the project and its purpose, enhancing their identity-based commitment and as a result they are more stable in the face of membership turnover (Abrams et al., 1998). This finding is in line with theory (Haythornthwaite, 2009) and research (Eveleigh, Jennett & Blandford, 2014) that associate intrinsic motives with a greater number of contributions, but it also suggests that intrinsic motives, such as interest in the topic, is linked to longer stay in the community.

An overall comparison between the categories shows 'persistent' members to be the least satisfied with the missions and the participation, and this may explain their low activity level in combination with their long stay. In contrast, 'loyal' members demonstrate high levels of satisfaction in relation to the community, the members, the missions, and finally the learning experience combined with experts' presence. Most of the experts fall into the 'visitors' category and thus they had no more than two active days in the project.

7.3.4 Participation behaviour and sustaining engagement

As Citizen Inquiry projects aim to engage the community in more than one inquiry activity (e.g. creating investigation, sharing data and comments, posting on forum), members express their preferences in one or more activities, according to their particular participation goals. While Inquiring Rock Hunters were mainly using forum posts for their discussions, further analysis of the interactions on Weather-it community has shown that Weather-it members interacted more through mission and data comments rather than forum posts (Aristeidou, Scanlon & Sharples, 2015a).

Research on engagement has found that usually only a small proportion of members participates in the project forums (Romeo & Blaser, 2011). However, Citizen Inquiry communities offer more ways for interaction with other members, beyond forums, allowing them to comment on the investigations and the individual data, and this might be the reason that has led to a large percentage of members participating in discussions.

Research also suggests that the type of activity in citizen participation projects may be driven by different motivations (Raddick et al., 2013). In this thesis there was an attempt to cluster members based on their activities and understand the behaviour of every activity group by observing their participation patterns. In the final analysis, while clustering was not possible, the reason for the failure indicates the diversity of the activities in which the members were engaged. Hence, members got involved in contributing missions, data, comments, forum posts and votes. However, the one third of the members were only watching and not contributing to any investigation ('Watchers'). Moreover, there were also several members who primarily engaged with a specific type of activity (i.e. 'voter', 'commenter') or had exceptional participation (i.e. 'extreme contributor') (Section 6.4.3).

One design aspect that could improve and sustain the participation within the community based on the members' activity is a mechanism for suggesting similar missions or discussion topics to the ones they already participate in. Moreover, more personalised communication with members

having the same interests could enhance their motivation for staying in the community. On the other hand, sharing and interaction may be enhanced with the improvement of the social technologies in the platform, as mentioned in previous sections.

7.3.5 Variety and interaction for sustaining engagement

Findings of this thesis show that overall, the social aspect, the variety, and the concept of Citizen Inquiry were factors that sustained the engagement of members who remained active in the Weather-it community until the end of the project. As mentioned above, multiple ways of participating acknowledges many interests and motivates members' participation (Bonney et al., 2015). In Weather-it, this idea is enriched with not only the variety of data collection methods that missions were providing, but also with the diversity in topics, locations, members and their level of expertise, which made their participation more interesting (Section 6.4.4.1). Furthermore, Weather-it and the nQuire-it toolkit supported the interactions between the members through an open participation approach which is suggested to enhance the sense of community and leads to higher levels of engagement (Jennett et al., 2013; Jennett & Cox, 2014). As a result, Weather-it members felt welcome to the community and satisfied with their active roles and the number of new available activities (Section 6.4.4.1). Findings have also shown that their contentment with the Citizen Inquiry community may be associated with the fact that they had the option to create their own mission or help others with their missions, finding this interaction a fun way of learning and getting engaged with science. Also, a Weather-it member who was volunteering in citizen science projects had also stated that Weather-it had more interaction between the members than other projects (Section 6.4.4.1). For instance, research in the Old Weather project has shown that volunteers were more interested in solitary experience and thus it was suggested that independent working should be facilitated towards more personally-set goals (Eveleigh et al., 2014). Unlike the Old Weather project, most of the factors that motivated Weather-it members to remain active in the community were interaction-oriented, suggesting the facilitation of interactive participation and collaborative choices.

7.3.6 Preventing disengagement

The disengagement of Weather-it members from the community was related mainly to time constraints and secondly to lack of interest in the available topics (Section 6.4.4.2). Moreover, lack of experience and low self-confidence were also reasons that several members from both Weather-it and Inquiring Rock Hunters gave for their decision to abandon their investigations and the communities.

Lack of time, which was repeatedly stated by Weather-it members, has also been encountered in other citizen participation communities, such as Old Weather (Eveleigh et al., 2014) and the Bentham Project (Causer & Wallace, 2012). A suggestion by Eveleigh et al. (2014) for deterring dropouts due to time constraints, was breaking down of tasks into smaller items, and ensuring the compatibility of mobile devices. But, against that, mobile devices can be more difficult and fiddly to operate than a web-based system. In addition to the hosting platforms and devices, project communication could play a significant role in attracting non-active members back to the community during the periods they are not very busy. For instance, it was noticed that Weather-it members had lower variation in periodicity, in comparison to Milky Way and Galaxy Zoo projects, and hence several non-members were coming back to the community when interesting topics were announced.

However, lack of interest in the Weather-it topics was also a reason for several members to abandon the community. Although members could create their own investigations sparked by their everyday life experience, it was noticed that the majority were expecting that other members would create missions and that they would contribute to those missions. Consequently, some suggestions for improving the retention of these members in Citizen Inquiry communities are the provision of a more personalised reference system that would inform them about topics of their interest or the provision of more support to create their own investigation.

One of the reasons several members did not proceed to create their own mission in Weather-it (Section 6.4.4.2) or to answer their own research question in Inquiring Rock Hunters (Section

4.8.2), was the lack of confidence they had due to their limited experience on the topic. This fear of not being good enough has also been encountered in the Bentham project (Causer & Wallace, 2012) and it was suggested that the project team should provide more reassurance that all contributions are valuable. Research on low confidence of Old Weather members has shown that personalised feedback could also facilitate in affirming the quality of contributions and as a result reducing members' anxiety (Eveleigh et al., 2014). However, feedback and mentoring by experts may be time-consuming and expensive. Citizen Inquiry communities could address this issue by exploiting their social aspect and form supportive groups containing experts to enhance the discussion on the contributed data and comments.

7.4 How can Citizen Inquiry participants adopt an inquiry process that follows good practices of science learning? (RQ3)

Promoting the learning of scientific content or processes has been one of the main objectives in several citizen science projects (Freitag & Pfeffer, 2013). In Citizen Inquiry, knowledge sharing is the main goal (Section 2.4). Thus, the educational outcomes of the Citizen Inquiry communities were also measured through the understanding of science content and processes. The evaluation focused around the inquiry skills members may have improved from their participation in the projects. Those inquiry skills involve activity, on-topic and community learning (Kloetzer, 2013). Finally, an overall evaluation is linked to the attitude toward science and the production of new science. Most learning in the communities was incidental and instruction and was spread by *"picking small things up"* (Kloetzer, 2013).

7.4.1 Activity learning

The collected data from both Citizen Inquiry communities suggest that members firstly learn the mechanics of the project, including the concept, the software, the rules and the available types of activities. For instance, rock hunters first studied the tutorial to orient themselves in the platform and then attempted to create their own investigations while exploring the available tools.

Likewise, Weather-it members were allowed to browse the available missions before registering with the nQuire-it platform and then, register and get engaged with their preferred ones.

At this level, members are engaged with micro-learning activities (Kloetzer et al., 2013) and thus, they might learn through their engagement in particular inquiry processes: forming a research question/creating an investigation, deciding on research methods and tools, collecting and analysing data, concluding with results, discussing and reflecting on the conclusions.

Creating an investigation involves members in developing a research question or/and hypothesis and articulating their thoughts about a problem they encounter in their everyday life. As a result, alongside co-created projects, Citizen Inquiry has a great potential to achieve a wider range of citizen participation, as members ‘translate’ their questions into research projects (Bonney et al., 2009; Shirk et al., 2012; Bonney et al., 2015;). For members who have not formed their own research question, they can decide how to contribute to other people’s research, based on their preferences for topics and research methods.

Findings from both Weather-it and Inquiring Rock Hunters have shown that many members, mainly beginners, found it difficult to form their research question or they did not feel confident to create an investigation. Moreover, the majority of Weather-it members invoked time constraints or admitted they did not have any ideas (Section 6.4.4.2). A comparison between the two projects demonstrates a quite large difference between the numbers of published investigations; 50% of the registered rock hunters published an investigation (Section 4.8.2), while the equivalent percentage for Weather-it registered members is 7% (Section 6.2). A potential response on that difference came from a member of both communities who although she liked the variety of mission types in Weather-it and found it very enjoyable, suggested that the guiding Inquiry Framework in Inquiring Rock Hunters was useful for “deeper” research (Section 6.5.7).

Similar comments by rock hunters who created their own investigations highlight the importance of the Inquiry Framework in guiding them through the inquiry phases (Aristeidou et al., 2014). Whereas visualisation of the inquiry phases for rock hunters also included the available tools

needed at every phase, the Weather-it missions depended on selecting tools for data collection at the start of the mission. As a result, Weather-it members had to choose from the beginning the appropriate type of mission for the investigation they wanted to create or join. For instance, Spot-it missions were the most popular as they were found to be easier, accessible and more exciting [Questionnaire B].

In data collection, Citizen Inquiry members improved skills similar to those of contributory citizen science projects: e.g. they learn how to observe and identify objects as in iSpot (Woods & Scanlon, 2012). In this stage the members used tools for the data collection and data publication, developing alongside tool manipulation skills. For instance, rock hunters took pictures of rocks and uploaded them to their investigation. Weather-it members recorded sunlight samples and uploaded them to the mission. In both cases members had to use the correct tools and then select, record and upload the appropriate data.

Findings from the Sense-it use for the 'Record the sunlight' mission (Section 6.5.2) suggest that the majority of the measurements (95%) were valid, containing the right time, duration, label and data collection method (non-wavy plots). However, the data gathered from sunlight measurements in the same area identified further calibration issues with the light sensors (Section 6.6.5).

Beyond data collection, data analysis was the inquiry process that would allow members to compare, visualise, classify, and describe (e.g. date, temperature, etc.) their collected data. In both projects there was a request for more data manipulation tools to be embedded in the platforms in order to facilitate this inquiry phase (Sections 4.8.5 and 6.6.3.2). Although Inquiring Rock Hunters project provided a spreadsheet tool by which the investigator could import measures and then create graphs, Weather-it did not provide any tool for data analysis. As a result, two Inquiring Rock Hunters did a statistical analysis through the platform; the only Weather-it member who did some statistical analysis did not publish it on the platform, but only posted his conclusions (Section 6.5.3.1). As feedback on both projects has suggested, there is an

important tool limitation. For enhanced engagement with the data analysis inquiry phase, the integration of several data manipulating and field-related tools is considered essential.

As in citizen science projects, Citizen Inquiry communities provide members the opportunity to participate in the process of asking and answering authentic questions (Jordan, Crall & Gray, 2015). Inquiry results of both Inquiring Rock Hunters and Weather-it projects were open to all the members, and the discussion through comments was the most popular activity in the community. Part of the dialogue was also a “debate” on the quality of the data which was demonstrated with the members’ thumbs up or down on the items. For instance, Win-it participants could vote for their favourite text response to a research question. This voting technique leaves room for improvement as it has been noticed that the most voted may not always be the correct response, and this may lead to misconceptions. Furthermore, members were demonstrating diverse interaction behaviour whilst reflecting with the data, results, and other comments (Section 6.5.5).

7.4.2 On-topic learning

On-topic learning refers to the content knowledge related to the scientific topic explored in the Citizen Inquiry communities. Beyond the engagement with the inquiry phases, a macro-level of learning happens when members learn about the science field by participating in discussions, looking up information on the Internet and expanding the community environment with their own contributions (Kloetzer et al., 2013). Science field knowledge was the most frequently-mentioned learning outcome by both Inquiring Rock Hunters and Weather-it members (Section 4.9.6 and Section 6.5.7).

Forum and investigation discussions happened to a greater extent in Weather-it than in Inquiring Rock Hunters. A significant aspect of scientific discussions is the specifically specialist language of the area of science (Parry, 2009), and thus vocabulary analysis of the discussion content provided some insight into the language use of Citizen Inquiry members. In both Citizen Inquiry communities, the most frequently used words was vocabulary related to the scientific field and

particular investigations, or verbs and words used to describe science (Section 4.8.6 and Section 6.5.6).

Nevertheless, in Inquiring Rock Hunters the existence of Google Copy Paste Syndrome (GCPS) (Weber, 2007) was detected, as non-experts had retrieved and used some easily available digital content that did not represent their personal knowledge. Weather-it members seemed to be more comfortable to use their own vocabulary. There is evidence that Weather-it vocabulary had progressed between the first and the last week of the project (Section 6.5.6). A tool that allowed the input of online glossary to particular investigations would provide direct access to the 'language culture' of the specific field and improve members' confidence and vocabulary quality.

In contrast to contributory citizen science projects, the creation of investigations by members produced a range of themes, allowing members to get engaged in various fields and gain knowledge on more than one topic. For instance, Inquiring Rock Hunters got involved in location-based investigations on rocks and also in exploring soil and plants. Likewise, Weather-it members participated in investigations of weather phenomena and climate-related discussions. This variety, as described in Section 7.3.5, not only has maintained their interest in the community but also provided access to more opportunities for science learning.

What was missing from both projects was the specialised in the field tools and in some cases learning materials. While Inquiring Rock Hunters made available generic learning material on rocks and their investigation, Weather-it has only supplied members in missions with information about the specific topics. It is possible that easy access to domain knowledge and tools would spark members' curiosity and enhance their involvement with new investigations and research methods. Access to domain knowledge may be available through blog posts, as proposed by Druschke and Seltzer (2012), or via some more interactive video-conferences by experts. Furthermore, it is suggested by the researcher that experts should contribute more to the software design and selection of tools, for the members' greater understanding of field tools and methods.

7.4.3 Community learning

Citizen Inquiry communities aim to enable social learning through interactions between the members and thus enhances community learning which happens both during activity and on topic learning (Kloetzer et al., 2013). Therefore, learning may happen through direct or indirect exchange with peers, which is supported by the community design, and through collaboration and communication with expert members in investigations and forums.

The usual interaction pattern in Inquiring Rock Hunters was for the non-experts to ask for help, the experts to guide, and the members of intermediate expertise to be inactive (Section 4.8.4). Also, only three investigations received feedback but without any follow-up discussion. The findings, overall, confirmed the active contribution of specific members only and the abandonment of the platform once the investigation is completed or difficult to finish. In Inquiring Rock Hunters, community learning seemed not to work very well; although members were receiving feedback when asking for it, the lack of engagement in the community could not facilitate their retention.

The Weather-it community alongside the improved design of the platform, allowed the formation of a different interaction pattern for community learning. The communication and collaboration on inquiries between the community members were enhanced in terms of quantity and type. Firstly, as members were allowed to create more than one inquiry and contribute data to other investigations, a larger number of interactions and contributions was produced (Section 6.2). Feedback on inquiries was more common and a number of them had also follow-up discussions (Section 6.5.5).

The types of community learning produced through the feedback and the follow-up discussions, involved interactions between and within experts and non-experts (Section 6.5.5). These interactions included non-experts imitating experts' observation techniques, oppositions between experts, and experts providing domain knowledge, mentoring and acknowledging non-experts to their inquiry efforts. However, Weather-it involved also several less-expected interactions, such as

non-experts acknowledging or opposing experts, as well as becoming mentors to other non-experts. This may be aligned to research claiming that expertise may also be found in people (non-scientific experts) who have sustained experience with an area of study outside of mainstream science; those people have contributory expertise sufficient to contribute to the construction of new knowledge (Evans & Collins, 2007).

Consequently, an important aspect that boosted community learning, beyond the platform design, is the several active experts in the community whose initially motivation to join was their interest in the topic (Section 6.3.2). Although Weather-it experts – a loyal member and an active visitor – exhibited eagerness to provide feedback to non-expert people, research from other projects has shown that the primary motivation for experts to take part in citizen science projects is to collect data and receive help with their research (Rotman et al., 2012; Curtis, 2015). This creates a barrier for Citizen Inquiry projects as the participation of experts is needed to secure the quality of contributions and conclusions.

7.4.4 Science and scientific literacy

Several measuring instruments for pre and post-tests have been developed for the detection of scientific literacy among citizen science projects participants. For instance Brossard et al. used a context-independent generic test (Brossard, Lewenstein & Bonney, 2005) and Cronje et al. (2010) have created a domain-dependent, context-specified scientific literacy instrument. As investigations in Citizen Inquiry communities are created by members and thus, are not known in advance, the creation of a context-specific instrument is not possible. For the same reason, the development of a pre/post-test based on knowledge items was not possible and therefore the evaluation was based on self-reporting changes in knowledge by participants.

The majority of Inquiring Rock Hunters stated that throughout their participation in the community, beyond the content knowledge, they also gained knowledge on how to approach an investigation (Section 4.8.4). This knowledge includes the phases of the inquiry process, science field research methods, and information about where to collect data from and how, and how to

manipulate those data. This self-report is in contradiction to Weather-it members whose reports mention gaining domain knowledge but made no reference to any research methods and process learning (Section 6.5.7). Other studies have also demonstrated evidence that a low percentage of participants are able to provide an acceptable description of what a scientific research is (Crall et al., 2012). Research showed that participants in 'Spotting the Weedy Invasives' had little change in process understanding (Jordan et al., 2011) and there is no statistically significant evidence that 'The Birdhouse Network' participants changed their understanding of the scientific process (Brossard et al., 2005).

In Citizen Inquiry communities there is evidence of members becoming engaged with experimental studies and the use of control variables. For instance, Inquiring Rock Hunters created investigations exploring the shape and size of rocks based on the location (Section 4.8.2). Weather-it did not engage members in control studies to a great extent (Section 6.2); only Sense-it users were more interested in experimentation than others. However, Weather-it might have facilitated the improvement of inquiry skills, such as argumentation, critique, discovery and reflection, by involving members in discussions on the investigation topics (Section 6.5.5). Such skills can be applied to future investigations and thereby improve the community's science literacy.

Furthermore, Weather-it members, unlike rock hunters, considered the community as a fun way to spend their free time and get engaged with science (Section 6.5.7). This attitude contradicts findings of public attitudes to science reports in which the public finds science and scientists serious (Ipsos MORI, 2014). This 'imbalance' between gains in scientific literacy and fun has also been noticed in other projects. It was observed that participants in the Birdhouse Network Project were more attracted to studying birds, rather than learning about scientific processes (Brossard et al., 2005). Likewise, participants of a project with the aim to learn how to monitor invasive plant species were more interested in the activity rather than the opportunity to learn about scientific processes (Cronje et al., 2010).

Changes in attitude among adults require many interventions over longer periods of time (Merriam, Caffarella & Baumgartner, 2012) and this might be one possible explanation about not finding any significant changes in the participants' attitude. Also, the level of participation is important for the internalisation (acceptance of a set of norms and values) of science learning and hence the acquisition of a science identity (Committee on Science Learning, 2007). However, even though the Citizen Inquiry projects due to time constraints did not run for a long time, they helped members to overcome some of the misconceptions they held at certain topics (e.g. that there is no extreme weather in southern countries) (Section 6.5.4.4).

As seen in Section 2.2.4, some of the scientific success measures of citizen participation projects are counting the numbers of publications on the project, the size and quality of data collection and the popularity of the project (Bonney et al., 2015). Nevertheless, Citizen Inquiry communities were not designed to fulfil science outcomes to a great extent. As a result, there were no scientific achievements. The quality of data collection were monitored and reviewed by experts throughout the project duration, and then analysed by the researcher and no new science knowledge was produced. However, experts participating in the project identified a potential in engaging members effectively in real scientific investigations and benefiting scientists (Section 6.5.8).

7.4.5 Off topic knowledge and skills

Off topic learning refers to transferable knowledge and skills, which are not directly related to the topic field but incur through the involvement of members with several tasks. The main skills reported in this research are related to the interaction between the community members and the engagement with the software.

Communication and writing skills: Online communication was widely present at the Citizen Inquiry communities and provided structured ways for the members to get engage with communication tools, such as forums and investigation discussions. Three participants mentioned improving writing skills as a motive for their participation in specific Weather-it missions [Questionnaire B],

however, there was not a pre/post-test on writing skills. There was also an obvious effort by non-English speaking people to take part in discussions.

Digital literacy: Several members in both projects reported gaining knowledge and skills in the field of digital literacy, according to their previous experience. For instance, as it was stated in the interviews and Questionnaire B, some rock hunters experimented with their mobile devices and camera on how to take and upload pictures and several Weather-it members on how to operate Sense-it application. They also developed web literacy skills by navigating the web and selecting credible resources to share with the community, for instance, information about earthquakes (Inquiring Rock Hunters), or the climate on Mars (Weather-it). Alongside, they practised skills in the appropriate use of copyright, by citing and acknowledging, when appropriate, the sources of their shared information.

Self-reflection: A main output of participation in Citizen Inquiry communities was self-reflection on what one is confident to do or not. Several members were concerned about making valuable contributions or misusing the software (Section 6.4.4.2). Finally, some made contributions and experienced them as being valuable; as a result they may have gained self-efficacy which affected their learning positively (Bandura, 1977). For instance, a member mentioned in her interview that she found it difficult to create a Weather-it mission, but after she achieved that, she said that it would be easy for her to create another one. However, some other members who were more obstructed by their concerns stated self-awareness as their new knowledge.

7.5 Researcher as Citizen Inquiry community moderator

Design-based research allowed the researcher to be a part of the communities and experience them in the way members did. Therefore, it was easier to observe the activities within the community, understand the satisfaction and struggles, and obtain a better image of the level of participation and engagement. Moreover, the role of the researcher in the community did not end with observation and better understanding. Ongoing changes were applied to the communities, where appropriate, in order to enhance the community success. Then, the impact

of the changes was measured in comparison to the previous status. A minor case was the detection of some software bugs by the researcher while contributing to the missions. A more significant example was the use of Wizard of Oz technique together with weekly email updates which, as a result, increased the rate of the community evolution (Section 6.3.5).

Furthermore, having the researcher involved in the communities possibly prevented some drop-outs, as there was personalised support towards the members. For instance, there was frequent communication with more detailed instructions to one of the members who found the software very difficult to use, even though they had a tutorial in hand (Section 4.8.5). In the end, that member completed their investigation. Also, members expressed their satisfaction for having immediate help when needed and recognised the moderator as being the person who was always there. Finally, their trust in the researcher assisted in obtaining good survey response rates with 86% and 38% for the questionnaire and the interviews, respectively, in Design Study 1; and 60% and 88% for the questionnaire and the purposive sampling interviews, respectively, in Design Study 2.

In addition to the trouble-shooting role the moderator had, she was also responsible for facilitating knowledge within the community. However, as the researcher was not an expert on any of the Citizen Inquiry community topics (i.e. geology and meteorology), her role allowed her to recruit and involve, when needed, other researchers in the design and facilitation of science learning within the community. Engaging and including people (mainly from The Open University) with expert knowledge, not only on the science topics, but also of the platform and inquiry learning provided scaffolding for people joining the investigations and aimed at the creation of a more vibrant community.

Being a moderator and a part of the community has also led to the identification of some aspects of the research that would create spaces for greater success. To this end, more weight was given to the creation and maintenance of the community for the design of the second study, in order to sustain participation and engage new and returning members.

7.6 Design considerations

This chapter draws together failures and successful strategies and design features of Inquiring Rock Hunters, Weather-it projects in this thesis and together with the experiences of other citizen participation communities. These do not aim to create grand theories applied to all contexts but aim to improve the design of online communities with similar conditions. The following suggested design considerations, resulting from the discussion above, may facilitate the creation, improvement and sustainability of citizen participation communities in which members will adopt good science and learning practices and enhance their science literacy:

- Support word-of-mouth advertisement by enabling easy sharing technologies: most memberships to Weather-it community were attracted through word-of-mouth advertisement between friends and colleagues. Citizen participation communities can facilitate word-of-mouth by enabling content sharing technologies and developing a more usable and welcoming design.
- Facilitate recruitment by promoting personal benefits from participating in the community: this is related to the idea of providing potential members reasons for joining the community. As in some citizen participation communities, members join due to personal benefits, the promotion should focus upon those desired benefits. For instance, if members are interested in learning more about the research topic, the material should be designed to fulfil this personal demand. Likewise, benefits for experts should be given particular attention. It is suggested that experts interested in public engagement would be ideal for Citizen Inquiry communities, as these communities currently do not offer any benefits of scientific nature, such as publications. However, public engagement strategy is an increasingly important element of science research grant applications and that could be a motivation for boosting participation by scientists.

- Know the profiles of the community members: meeting the members of the communities and their ongoing level of engagement helps in understanding how successful the design is and improving the aspects that benefit the retention in the community.
- Design usable and useful software: software may be a reason for potential members to stay or leave the community, thus it is important that the software usability will be tested by technology and human computer interaction experts. Supporting ongoing feedback by members may also reveal bugs and needs, and improve the software design.
- Maintain frequent communication with the community members: increase of contributions and interaction between the members, as well as community identity sense, were mainly consequences of Weather-it commencing email notifications and updates. This proves the influence of project communication to the community revitalising. Evidence of the efficiency of the frequent communication, is the expiry of the community a few weeks after the email notifications and updates stopped due to the end of project duration.
- Include platform built-in functions for moderators: the importance of the moderator for the sustainability of the community urges that a platform with build-in functions may help in the facilitation of the participation. Such functions may include bulk emails and notifications to the members of a specific mission or forum thread. For instance, an email informing about the final results of a mission or inviting members to a similar mission.
- Plan for a longer period of community growth: moderator is very important for the creation, sustaining and growth for the community but they should not be irreplaceable. The community should be maintained in case of moderator's unavailability, by securing continuing facilitation (e.g. through automated systems) or transition of moderation duties to other trusted community members that may contribute as facilitators.
- Balance between intrinsic and extrinsic motivations for longer stay and more contributions: the level and duration of members' participation depends on many factors. It is suggested that extrinsic motivations, such as interesting software, may enhance the number of contributions,

but intrinsic motivations, such as more opportunities to learn about the topic, would facilitate longer stay in the community.

- Demonstrate comparison tables: this feature aims to the enhancement of extrinsic motives and has a twofold character. First to acknowledge top contributors and second to spark competition between the members.
- Optimise community design to sustain engagement: interactions between community members is a very important aspect for sustaining engagement in the community as it is more likely to develop a sense of community identity sense and sustain longer engagement in the community. Moreover, the provision of more social technologies provides opportunities for deeper discussions around investigations.
- Support variety in topics and ways of engagement: multiple ways of engaging in the community and the investigations motivate members' participation. Thus, members should be aware of the available participation options and able to create new topics, related to their interests. A solution for that is to facilitate diverse types of investigations based on the data collection and analysis settings able to engage in a variety of topics.
- Facilitate collaborative working: interaction and communication with other members during the investigations was one of the aspects that most members liked in the community. This suggests that design for more collaborative investigations may increase members' retention in the community.
- Update members with to-do lists of smaller or similar tasks: dropping-out of participation is strongly associated with lack of time and interest. However, some members may revisit the community after they dropped out; lists with small investigation tasks with time duration or tasks similar to the ones they showed some interest in, may support their return.
- Promote support groups to facilitate members' confidence: members' anxiety about the quality of their contributions is a drawback that may be overcome with the creation of experts leading supporting groups that discuss the data and comment on contributions.

- Design explicit inquiry activities as part of a complete scientific process: engaging members with several phases or the entire scientific process requires preparation with aim, activity, tools and research methods instructions for each phase. Furthermore, information about the entire scientific process and where each inquiry phase lies may facilitate scientific literacy to a greater extent.
- Collaborate with experts to make available on-topic culture and learning: a large number of members join projects to learn more about the science topic supported by Citizen Inquiry or other citizen participation communities. Providing access to the culture of the science topic would sustain their interest and increase the inquiry outcomes. This involves content and research methods knowledge and access to the science topic vocabulary and the field tools. Science experts are the appropriate people to convey this culture, participating in the inquiry design and tools.
- Aim to balance fun and gains in scientific literacy: it is important that the community design will deliver a pleasant and fun environment for sustaining engagement in the community but will also promote scientific literacy. Hence, the design should take into account factors – mentioned above – that improve both. The facilitation of the development of transferable skills for future use in the community: engagement with scientific investigations does not only require inquiry skills, but also other transferable skills that may help in better learning and scientific outcomes. An example is the provision of opportunities for improving writing and communication skills, digital competence and self-efficacy.

7.7 Scalability of Citizen Inquiry projects and applicability of design considerations

Scalability of Citizen Inquiry projects would require a design able to handle and accommodate a growing community of members and investigations. Scaling up the Citizen Inquiry projects employed in this PhD research – with the current settings and available technologies – could be a great challenge. The main issue of enlarging the communities is the capability of the moderator to accommodate that growth and maintain the facilitation of community and individuals. Bringing Citizen Inquiry to scale may require a design that is flexible enough to be used in a variety of

contexts and by a variety of community members, while being robust enough to preserve effectiveness in science learning.

In information technology services, scalability is facilitated in mainly two complementary ways: automation and individualisation (Clarke, Dede & Ketelhut, 2006). Citizen Inquiry communities can benefit from automation by simplifying actions by moderators and pre-setting, when possible, some activities of the software. Technologies reported in the design considerations section (Section 7.6) could aid this automation. For instance: (a) word-of-mouth and therefore, recruitment, can be enhanced by automated content sharing technologies on every aspect of the community that members would like to share with their networks, (b) built-in functions can support bulk emails and notifications to all the members or specific groups (mission, forum topic), and (c) better scaffolding system that will be able to support, guide and inform members in every step of the inquiry process.

Individualisation can assist Citizen Inquiry by producing options tailored to a variety of preferences and levels of experience. In this way, members will be able to choose or customise their way of participation in the community. A prerequisite of individualisation – co-design – has already been an essential part of Citizen Inquiry philosophy. The design of Citizen Inquiry communities builds on member needs and perspectives. Therefore, some design suggestions that could assist in building a more individualised system are as follows: (a) a variety of ways to participate in the community, such as more types of investigations and (b) a recommendation system that delivers to-do-lists to members, according to their interests.

However, technology design for scale has also its limitations. On the one hand, it costs in terms of price and time and on the other hand, this design will never reach people who are so unengaged that they drop-out on their first visit. Consequently, scalability of Citizen Inquiry communities should also involve further human intervention, with multiple moderators and experts dedicated to the community. Thus, while technology intervention requires more resources, the application

of some of the human resources-related design considerations involves further research on how to recruit, engage and organise members and experts in moderation and scaffolding duties.

Chapter 8: Conclusions and Future Research

8.1 Introduction

The purpose of this PhD research was to explore the creation of an active and sustainable online community for citizens to engage in scientific inquiries. Citizen Inquiry communities enable the engagement of citizens in the entire investigation process whilst conducting personally meaningful investigations in a social environment with expert scientists and non-experts. It explored whether and how non-experts can engage in this challenge of Citizen Inquiry.

A design-based research approach was adopted in order to investigate the thesis research questions raised in Chapter 1. The intervention consisted of two iterations which utilised mixed methods for the analysis of the outcomes: the initial design 'Design Study 1' and the more extensive design 'Design Study 2'. The iterations were developed around the Citizen Inquiry communities 'Inquiring Rock Hunters' and 'Weather-it', with the use of the nQuire platform and nQuire toolkit (nQuire-it platform and Sense-it app.), respectively. Each design-based study set its particular objectives and approaches to create and develop the online communities. The research questions were addressed through a variety of data collection (interviews, log files, questionnaires, usability scales, focus group and researcher notes) and data analysis methods (thematic analysis, content analysis, social network analysis, clustering and graphs).

The contributions of this thesis to enhance understanding on how to create online communities of citizen participation includes a review of: the typologies and informal learning within public participation in scientific research projects; current theory and practice of online communities; user engagement and motivation practices within the online communities; and approaches and methods for creating, sustaining and evaluating the community creation, engagement and science

learning. The final product demonstrates design considerations for the creation of future Citizen Inquiry and other citizen participation online communities.

8.2 Thesis questions revisited

The contributions and findings reported in the discussion chapter are summarised here in terms of answers to the three main thesis questions:

How can we create a sustainable online community for Citizen Inquiry?

One aim of this PhD research was to explore the creation of a sustainable community in which people would be engaged in scientific investigations. This question emerged after the outcome of the first iteration 'Inquiring Rock Hunters' which did not sustain the participation of members in the community. The investigation of this question involved studying both software design requirements and community engagement strategies. The research was facilitated by a combination of collected data log files, focus group, interviews, questionnaire responses, system usability scale results, and observations by the researcher/moderator. The results from the data analysis, demonstrated the level of success of various strategies and technologies used in the online communities.

The findings from this thesis have added to the body of current research into recruitment of members to online citizen participation and other communities. Word of mouth was found to be the most powerful means of recruitment based on questionnaire responses. Word-of-mouth can be facilitated by enabling easy content sharing technologies that allow sharing each piece of an artefact created within the community and help in the promotion of it. In addition, recruitment can be improved by promoting personal benefits from participating in the community (e.g. learning), addressing the main motivation of Citizen Inquiry members to join the community as resulted from the questionnaire responses in both design studies. Furthermore, there should be a balance in the emphasis between features that focus on intrinsic and extrinsic motivations, as

they facilitate different types of participation. For example, the interest of 'loyal' Weather-it members in the topic of the community has shown that intrinsic motives are linked to longer stay.

The findings have also shown that the design of usable software is an important factor to sustain participation in the community. The software may be the reason for participants to stay or leave the community, and thus it should go through early evaluation by experts and follow up feedback by members. Beyond the software design, several other strategies for maintaining the level of participation are also important. The strategy which has the most influence, applied to Weather-it was the establishment of frequent communication with the community members, which reinvigorated the community and boosted the sense of community.

How can Citizen Inquiry engage members of the general public with investigations?

Another important aim of this thesis was to investigate how members were engaged with the investigations and what were the reasons for some members to drop out from the community. This question was inspired by research outcomes into community engagement in Inquiring Rock Hunters (Chapter 4) and other citizen science projects (e.g. Eveleigh et al., 2014) and online communities, which face issues maintaining people in the projects/communities (e.g. Malinen, 2015). Exploring engagement mainly involved visualisation of the contributions and interactions, through charts and social network graphs, backed up by survey material relating to engagement and disengagement factors.

Findings from a comparison between other citizen science projects and Weather-it, which engages participants in the additional scientific processes of proposing and managing projects, showed that the level of activity for Citizen Inquiry members was lower than Milky Way Project and similar to Galaxy Zoo, but with longer participation (Section 6.4.1). Some factors that motivated the engagement of members in the community and could help improve the design are the multiple ways of participation in the community and the investigations, the interaction between the members, and the opportunities for collaborative work and learning. On the other hand, to-do lists recommending smaller and similar tasks could facilitate the return of people with

lack of time or interest, and supporting groups could reduce the anxiety of members who have low self-confidence. The evidence from the number of contributions between the project duration period and end of facilitation supports the importance of project communication (i.e. email weekly updates, email notifications, social network updates) and the essential role of the moderator in a community.

How can Citizen Inquiry participants adopt an inquiry process that follows good practices of science learning?

The last but equally important objective of this thesis was to explore science learning through participation in Citizen Inquiry. Although science learning and literacy is one focus in many other citizen participation projects, it is argued that involvement with all the aspects of scientific process increases learning outcomes (Bonney et al., 2009). Learning outcomes in Citizen Inquiry were explored through the members' contributions, and self-reports on their learning gains.

Findings showed that the two Citizen Inquiry communities engaged members in science activity learning through their participation in the inquiry processes with a variety of tasks (e.g. research question formation, data identification, data description, data manipulation, sensor measurements, creating graphs, etc.). Furthermore, they practised on-topic learning through their involvement in discussions about the content knowledge, their familiarisation with methods and tools used in the field and their individual research on the topic of their interest. Both types of learning were supported by the interaction with others in the community. Finally, scientific literacy gains were difficult to measure, but there is evidence of some members getting engaged with the scientific process, improving inquiry skills and having a positive attitude towards science. Members have also practised transferable skills, such as communication and writing, digital literacy and self-reflection skills.

Reflection on the findings have led to some design suggestions for Citizen Inquiry projects that aim to facilitate the understanding of inquiry activities as part of a complete scientific process, balance the enjoyable part of the project with gains in scientific literacy, and improve transferable

skills. Furthermore, field experts' contribution to the communities is highlighted for the provision of quality science topic culture and learning.

8.3 Theory advancements

This PhD work has provided some documentation and reflection to produce design principles that improve the practice within Citizen Inquiry and other similar citizen participation efforts. Furthermore, the consistency of results and conclusions obtained in the two design studies, which were conducted in two diverse online communities of citizen participation with different scientific topics, suggest some advancement of theories underpinning Citizen Inquiry: citizen science and inquiry-based learning. Reflection on the conclusions informs the research around citizen participation in scientific investigations.

In Chapter 2 (Table 1), a typology of PPSR projects was presented, considering five levels of project typologies, based on the level of participation and the goals of every project type. The findings of this PhD research suggest that Citizen Inquiry can claim a position in Level 5, together with extreme citizen science and collegial projects. The difference between Citizen Inquiry and these project types is that citizens are required to facilitate the investigations, advancing in this way their role and addressing concerns around the function of citizens in PPSR projects (see Section 2.2.5).

This facilitation of investigations by non-expert scientists required a better scaffolding system design that allowed guidance in every inquiry step. This supporting mechanism – provided within Citizen Inquiry communities – tackled some issues around the facilitation of citizen-led investigations. In the future, it may also contribute to the dialogue about bottom-up PPSR projects, by providing some suggestions and solutions to questions around scaffolding and maintaining these types of projects.

This scaffolding mechanism has employed inquiry-based learning and collaboration between experts and non-experts. Although inquiry-based learning has been used in school education, this research on Citizen Inquiry, rather than involving a teacher, utilised the presence and

contributions of expert scientists in the community. This collaborative learning and communication is rooted in Vygotsky's theory (Vygotsky, 1980) that highlights the importance of learning through interaction and communication with others, rather than through independent work. It also builds around the concept of the zone of proximal development, as inquiry patterns within the Citizen Inquiry communities (see Section 6.5.5) have shown that citizens learned how to accomplish tasks through guidance by the more advanced community members.

This set of skills and knowledge gained by citizens in this research provides evidence-based learning to enrich evaluation frameworks for learning outcomes within PPSR projects. This PhD work focused and distinguished types of learning within Citizen Inquiry communities, such as vocabulary enhancement, misconception diagnosis and inquiry skills development. As learning outcomes and frameworks for evaluating them are limited in the field of PPSR, this evidence-based research may contribute to enriching existing frameworks (e.g. Kloetzer et al., 2013) or become the starting point for new ones.

8.4 Limitations of current work

Although the research has reached its aims, there were some unavoidable limitations. First, in each Citizen Inquiry community, only a small number of participants took part and thus, it is unlikely that the results are representative of an extended Citizen Inquiry community, developed over a longer term. The small number of experts and their limited contribution during the community preparation and project period was also a drawback that may have influenced the scientific nature of the communities.

Second, although part of this research has focused upon the enhancement of scientific literacy, it was not possible to provide quantitative detailed information about the change in knowledge, skills and attitude before and after the intervention. The use of an instrument designed for the needs of Citizen Inquiry community would be useful to measure any potential changes and compare these to efforts made in other projects. However, the administration of instruments in informal learning, such as pre/post-tests, to members who are volunteers should be made very

cautiously as it may lead them to drop out of the community, particularly if they are new members.

Finally, while the use of the nQuire-it platform has enabled direct access to the log files and Google analytics site and allowed the implementation of design requirements, more time would allow additional enhancements (e.g. demonstration of top posters, badges, etc.) that would further improve the system. Implementation of those enhancements would also allow further exploration of their impact and success level on the online communities.

8.5 Agenda for further research

This thesis has made contributions to knowledge regarding specific aspects of engagement and scientific learning in Citizen Inquiry communities, but has also sparked a set of research questions to continue the inquiry about how citizens' engagement with scientific investigations can be improved. The current study has provided a snapshot into two Citizen Inquiry communities, how they were created and developed over time, how members interacted with each other, in what way they were engaged with the inquiries and what they gained out of their participation in Citizen Inquiry. During the investigation of those aspects, other factors that may contribute to the successful engagement of people with scientific inquiries have emerged.

How can expert scientists be motivated to join Citizen Inquiry communities?

Investigating who participates in Citizen Inquiry and their motivations for joining the communities has revealed that a small percentage of the community members are science experts. In Inquiring Rock Hunters, scientists were invited separately to serve the expert's role in the community and accordingly, they maintained the role of the mentor and did not create any investigation or get involved in discussions unless providing feedback to non-experts. On the other hand, Weather-it experts joined the community in the same way as other participants and got involved in inquiries and discussions, even created their own investigations. However, they were unsure what their role was in the community.

This role ambiguity is missing from other citizen participation projects as they are often top-down and researcher-driven with clear benefits for the scientists: access to data, publications, etc. Citizen Inquiry communities do not involve extrinsic motives for scientists when recruiting them to the projects. Nevertheless, feedback by experts on Weather-it (Section 6.5.8) mentions outreach as a benefit, as it helps them to improve their understanding of the field better by explaining it to lay people. Hence, outreach may be one of the advertised benefits for scientists to join the community. Furthermore, it was also mentioned by experts that there is potential for data collection in Citizen Inquiry communities. Although that would make a powerful motive for scientists to join, further investigation needs to be done, so that the nature of Citizen Inquiry communities are maintained and not fall within the contributory citizen science projects.

How to eliminate reasons for disengagement?

Beyond the engagement factors that facilitate members' retention to the community, disengagement factors are also important for preventing drop outs. In both Citizen Inquiry communities members mentioned reasons that made them leave the community or leave their investigations incomplete. The main reasons for dropping out were lack of time, interest and confidence and also software usability.

Several solutions were suggested in the Discussion (Chapter 7), such as creation of smaller tasks, provision of personalised updates and multiple languages that may be able to reduce the causes of disengagement. Yet, further investigation on engagement may provide and test more ideas for preventing disengagement through interventions. For instance, comparative case studies using different interventions could address which factors influence members' retention to the community. Finally, the ideal size of a Citizen Inquiry community in order to be effective should be investigated further.

How to sustain a community of Citizen Inquiry?

As reported in this PhD thesis, sustainability is one of the main research topics of citizen participation and other online communities. The sustainability of the community does not only depend on the hosting platform and the tools, but also on the facilitation by moderators. The design of Inquiring Rock Hunters did not provide many opportunities for interaction and discussion and therefore, the participants left the platform once they finished with their own investigations, or even before that. Weather-it went one step further and provided tools that supported the interaction between the members while enhancing the sense of community. However, the findings revealed that the design itself was not sufficient in sustaining the community, as the contributions were gradually reduced once the facilitation period was over. Thus, a self-sustaining community is not a very realistic solution.

An option is continuous facilitation of the community with the help of built-in moderation tools that will make the administration easier. This solution suggests that if the community is planned for a longer period of growth, a number of moderators should be available regularly and constantly. Nevertheless, this option requires not only trusted loyal members to act as community facilitators, but also science expert volunteers to support the science learning aspect. Another option may involve Citizen Inquiry being a part of a citizen science community that already has researchers acting as facilitators. Anyhow, a future intervention should aim to explore a number of possible ways of sustaining a Citizen Inquiry community and provide insight into the most successful techniques.

How can fun and scientific learning outcomes be balanced?

Several citizen participation projects have reported that the participants joined because they are interested in the topic and to learn more about it, yet they report no evidence that they learn about the scientific process. In Weather-it, although the members did not include scientific process learning gains in their self-reported knowledge, there is evidence from their activity within the investigations that they practised the scientific process. Then again, Inquiring Rock

Hunters had many self-reports on learning about research process, phases and tools but members have not considered their participation “fun” to the same extent as in other projects.

This suggests that further exploration of the balance between the entertainment and scientific aspect of a Citizen Inquiry community is needed. Learning about the nature of science is an important part of Citizen Inquiry, but entertainment or engagement is also important for sustaining participation in the community. Visualising the scientific process with all the inquiry phases individually and conveying the culture of the scientific field in a fun way may enhance both aspects. Still, further exploration of this balance may also require developing instruments for measuring both aspects.

8.6 Final reflections

This PhD thesis investigated and addressed successfully research questions around the creation and sustainability of an online community for people to engage in scientific inquiries. To this end, components of inquiry-based learning and citizen science were synthesised and a design-based approach was used with success for the design and exploration of two different Citizen Inquiry communities. This research has considered a variety of aspects around the formation of the community: the software design, the engagement strategies, the interaction between the members, the engagement/disengagement factors and the science learning outcomes. It has provided evidence that Citizen Inquiry communities have the potential to engage people in scientific inquiries in an entertaining way while improving their scientific learning. Feedback from these first interventions on Citizen Inquiry provided some significant design guidelines, useful to developers and designers, that can be applied in future citizen participation communities. Future Citizen Inquiry communities must be supported so that members will be more engaged in the community, but also involved in all the aspects of the inquiry process and aware of the entire scientific process.

References

- American Association for the Advancement of Science. (1994). *Benchmarks for Science Literacy*. New York: Oxford University Press.
- Abrams, D., Ando, K., & Hinkle, S. (1998). Psychological Attachment to the Group: Cross-Cultural Differences in Organizational Identification and Subjective Norms as Predictors of Workers' Turnover Intentions. *Personality and Social Psychology Bulletin*, 24(10), 1027–1039. doi:10.1177/01461672982410001
- Akyol, Z., Arbaugh, J. B., Cleveland-Innes, M., Garrison, D. R., Ice, P., Richardson, J. C., & Swan, K. (2009). A Response to the Review of the Community of Inquiry Framework. *International Journal of E-Learning & Distance Education*, 23(2), 123–136.
- Alabri, A., & Hunter, J. (2010). Enhancing the quality and trust of citizen science data. In *Proceedings of the IEEE Sixth International Conference on e-Science* (pp. 81–88). IEEE.
- Alexander, A. (2008, January 15). From SETI@home to Hominid Fossils: Citizen Cyberscience Reshapes Research Landscape [Web log post]. Retrieved June 4, 2015, from http://www.planetary.org/blogs/guest-blogs/amir-alexander/setiathome_20080115.html
- Anderson, A., Huttenlocher, D., Kleinberg, J., & Leskovec, J. (2013). Steering user behavior with badges. In *Proceedings of the 22nd International Conference on World Wide Web* (pp. 95–106). Geneva: ACM.
- Anderson, D. P. (2004). *Public Computing: Reconnecting People to Science*. Paper presented at the Conference on Shared Knowledge and the Web, Madrid, Spain. Retrieved July 7, 2015, from <http://boinc.berkeley.edu/boinc2.pdf>
- Andrews, D. (2002). Audience-specific online community design. *Communications of the ACM*, 45(4), 64–68. Retrieved June 27, 2015, from <http://dl.acm.org/citation.cfm?id=505275>
- Angelino, L. M., Williams, F. K., & Natvig, D. (2007). Strategies to Engage Online Students and Reduce Attrition Rates. *Journal of Educators Online*, 4(2), 14 pages. AL: ERIC. Retrieved June 27, 2015, from <http://eric.ed.gov/?id=EJ907749>
- Aristeidou, M., Scanlon, E., & Sharples, M. (2013). A design-based study of Citizen Inquiry for geology. In *Proceeding of the Doctoral Consortium at the European Conference on Technology Enhanced Learning Co-located with the EC-TEL 2013 Conference* (pp. 7–13). CEUR.
- Aristeidou, M., Scanlon, E., & Sharples, M. (2014a). Inquiring Rock Hunters. In C. Rensing, S. de Freitas, T. Ley & P. J. Muñoz-Merino (Eds.), *Open Learning and Teaching in Educational Communities, Proceedings of the 9th European Conference on Technology Enhanced Learning, EC-TEL 2014* (pp. 546-547). Springer International Publishing.
- Aristeidou, M., Scanlon, E., & Sharples, M. (2014b). *Inquiring Rock Hunters* (Pilot Study Report). doi:10.13140/RG.2.1.4975.4323

- Aristeidou, M., Scanlon, E., & Sharples, M. (2015a). Weather-it Missions: A Social Network Analysis Perspective of an Online Citizen Inquiry Community. In G. Conole, T. Klobučar, C. Rensing, J. Konert, & É. Lavoué (Eds.), *Design for Teaching and Learning in a Networked World* (Vol. 9307, pp. 3–16). Springer International Publishing.
- Aristeidou, M., Scanlon, E., & Sharples, M. (2015b). Weather-it: evolution of an online community for citizen inquiry. In S. Lindstaedt, T. Ley & H. Sach (Eds.), *Proceedings of the 15th International Conference on Knowledge Technologies and Data-driven Business, i-Know 2015*, article no. 13. ACM Digital Library. Retrieved November 21, 2015, from <http://dl.acm.org/citation.cfm?id=2809567&CFID=579898034&CFTOKEN=54760676>
- Aron, A. (2012). *Statistics for Psychology 6th Edition*. Pearson. Retrieved July 19, 2015, from <https://books.google.com/books?hl=en&lr=&id=4-SsAgAAQBAJ&pgis=1>
- Assmus, G., Farley, J., & Lehmann, D. (1984). How advertising affects sales: Meta-analysis of econometric results. *Journal of Marketing Research*, 21(1), 65–74. Retrieved June 29, 2015, from <http://www.jstor.org/stable/3151793>
- Ballard, H. L., & Huntsinger, L. (2006). Salal Harvester Local Ecological Knowledge, Harvest Practices and Understory Management on the Olympic Peninsula, Washington. *Human Ecology*, 34(4), 529–547. doi:10.1007/s10745-006-9048-7
- Bampton, R., & Cowton, C. J. (2002, May 31). The E-Interview. *Forum Qualitative Sozialforschung/ Forum: Qualitative Social Research*, 3(2), article no. 9. Retrieved July 12, 2015, from <http://www.qualitative-research.net/index.php/fqs/article/view/848/1842>
- Bateman, P. J., Gray, P. H., & Butler, B. S. (2010). Research Note—The Impact of Community Commitment on Participation in Online Communities. *Information Systems Research*, 22(4), 841-854. Retrieved June 25, 2015, from <http://pubsonline.informs.org/doi/abs/10.1287/isre.1090.0265>
- Batson, C. D., Ahmad, N., & Tsang, J. (2002). Four motives for community involvement. *Journal of Social Issues*, 58(3), 429–445. doi: 10.1111/1540-4560.00269
- Bazeley, P. (2002). Issues in mixing qualitative and quantitative approaches to research. *AIDS*, 21(2), 91–98. Retrieved July 18, 2015, from http://www.dedoose.com/PDF/Bazeley_2002_Mixed_Methods_in_Market_Research.aspx
- Becker, M., Caminiti, S., Fiorella, D., Francis, L., Gravino, P., Haklay, M. M., ... Tria, F. (2013). Awareness and learning in participatory noise sensing. *PloS One*, 8(12), e81638. doi:10.1371/journal.pone.0081638
- Bell, P., Hoadley, C., & Linn, M. (2004). Design-based research in education. In M. C. Linn (Ed.), *Internet Environments for Science Education* (pp. 73-85). New Jersey: Laurence Erlbaum Associates, Inc., Publishers.
- Bell, P., Lewenstein, B., Shouse, A. W., & Feder, M. A. (2009). *Learning Science in Informal Environments: People, Places, and Pursuits*. Washington, DC: National Academies Press. Retrieved June 5, 2015, from <https://books.google.co.uk/books?hl=en&lr=&id=EzP737BHvrUC&oi=fnd&pg=PP1&dq=Lear>

ning+science+in+informal+environments:+People,+places,+and+pursuits.+&ots=7vfk4MdmNR&sig=TGfRzuljhaLacCM2GNI1M-bpXK8#v=onepage&q=Learning%20science%20in%20informal%20environments%3A%20People%2C%20places%2C%20and%20pursuits.&f=false

- Berge, Z. L., & Collins, M. P. (2000). Perceptions of e-moderators about their roles and functions in moderating electronic mailing lists. *Distance Education*, 21(1), 81–100.
doi:10.1080/0158791000210106
- Berger, J. (2014). Word of mouth and interpersonal communication: A review and directions for future research. *Journal of Consumer Psychology*, 24(4), 586–607.
doi:10.1016/j.jcps.2014.05.002
- Beuchot, A., & Bullen, M. (2005). Interaction and interpersonal in online discussion forums. *Distance Education*, 26(1), 67–87. doi:10.1080/01587910500081285
- Birks, M., Chapman, Y., & Francis, K. (2008). Memoing in qualitative research probing data and processes. *Journal of Research in Nursing*, 13(1), 68–75. doi:10.1177/1744987107081254
- Blum, J. R., Greencorn, D. G., & Cooperstock, J. R. (2012). Smartphone sensor reliability for augmented reality applications. In *Mobile and Ubiquitous Systems: Computing, Networking, and Services* (pp. 127–138). Springer Berlin Heidelberg.
- Bobek, D., Zaff, J., Li, Y., & Lerner, R. M. (2009). Cognitive, emotional, and behavioral components of civic action: Towards an integrated measure of civic engagement. *Journal of Applied Developmental Psychology*, 30(5), 615–627. doi:10.1016/j.appdev.2009.07.005
- Bohannon, J. (2009). There's power in a puzzle. *Wired*, 17(5), 106–109. Retrieved June 8, 2015, from <http://connection.ebscohost.com/c/articles/43100513/theres-power-puzzle>
- Bonetta, L. (2009). New citizens for the life sciences. *Cell*, 138(6), 1043–1045.
doi:10.1016/j.cell.2009.09.007
- Bonney, R., Ballard, H., Jordan, R., McCallie, E., Phillips, T., Shirk, J., & Wilderman, C. C. (2009). *Public Participation in Scientific Research: Defining the Field and Assessing Its Potential for Informal Science Education* (A CAISE Inquiry Group Report). Center for Advancement of Informal Science Education. Retrieved June 1, 2015, from ERIC database: <http://eric.ed.gov/?id=ED519688>
- Bonney, R., Cooper, C. B., Dickinson, J., Kelling, S., Phillips, T., Rosenberg, K. V., & Shirk, J. (2009). Citizen science: a developing tool for expanding science knowledge and scientific literacy. *BioScience*, 59(11), 977–984. doi:10.1525/bio.2009.59.11.9
- Bonney, R., Phillips, T. B., Ballard, H. L., & Enck, J. W. (2015). Can citizen science enhance public understanding of science? *Public Understanding of Science*, 25(1), 2–16.
doi:10.1177/0963662515607406
- Bos, W., & Tarnai, C. (1999). Content analysis in empirical social research. *International Journal of Educational Research*, 31(8), 659–671. doi:10.1016/S0883-0355(99)00032-4
- Bose, R., Buneman, P., & Ecklund, D. (2006). Annotating scientific data: why it is important and why it is difficult. *Proceedings of the 2006 UK e-Science All Hands Meeting* (pp. 739-747). Retrieved October 9, 2015, from

<http://www.allhands.org.uk/2006/proceedings/papers/713.pdf>

- Boston, W., Diaz, S. R., Gibson M., A., Ice, P., Richardson, J., Swan, K., & Journal of Asynchronous Learning Networks, v13 n3 p67-83 O. 2009. (2014). An Exploration of the Relationship between Indicators of the Community of Inquiry Framework and Retention in Online Programs. *Journal of Asynchronous Learning Networks*, 13(3), 67–83. Retrieved October 27, 2015, from <http://184.168.109.199:8080/jspui/handle/123456789/2259>
- Boyatzis, R. (1998). *Transforming qualitative information: Thematic analysis and code development*. Sage. Retrieved July 11, 2015, from https://scholar.google.com/scholar?hl=en&as_sdt=0,5&cluster=1468920955550384670#0
- Brabham, D. C. (2008). Crowdsourcing as a Model for Problem Solving: An Introduction and Cases. *Convergence: The International Journal of Research into New Media Technologies*, 14(1), 75–90. doi:10.1177/1354856507084420
- Brake, D. (2014). Are we all online content creators now? web 2.0 and digital divides. *Journal of Computer-Mediated Communication*, 19(3), 591–609. doi: 10.1111/jcc4.12042
- Brandtzæg, P. B., & Heim, J. (2008). User loyalty and online communities: why members of online communities are not faithful. *Proceedings of the 2nd International Conference on Intelligent Technologies for Interactive Entertainment*, article no. 11. Belgium: ACM digital library. Retrieved June 20, 2015, from <http://dl.acm.org/citation.cfm?id=1363200.1363215>
- Braun, V., & Clarke, V. (2008). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2), 77–101. doi: 10.1191/1478088706qp063oa
- British Geological Survey (2015). *Citizen Science at BGS*. Retrieved September 15, 2015, from <http://www.bgs.ac.uk/citizenScience/home.html>
- Brooke, J. (1996). SUS-A quick and dirty usability scale. In P. W. Jordan, B. Thomas, I. L. McClelland, & B. Weerdmeester (Eds.), *Usability Evaluation in Industry* (pp. 189-194). CRC Press. Retrieved July 29, 2015, from https://books.google.com/books?hl=en&lr=&id=IfUsRmzAqvEC&oi=fnd&pg=PA189&dq=SUS:+a+%E2%80%9Cquick+and+dirty%E2%80%9F+usability+scale&ots=G9lxC8kq0n&sig=ZbS_BC_Danvmhj2XKRRxwzAY4
- Brossard, D., Lewenstein, B., & Bonney, R. (2005). Scientific knowledge and attitude change: The impact of a citizen science project. *International Journal of Science Education*, 27(9), 1099–1121. doi: 10.1080/09500690500069483
- Brown, A. L. (1992). Design Experiments: Theoretical and Methodological Challenges in Creating Complex Interventions in Classroom Settings. *Journal of the Learning Sciences*, 2(2), 141–178. doi:10.1207/s15327809jls0202_2
- Brown, A. L., & Campione, J. C. (1996). Psychological theory and the design of innovative learning environments: On procedures, principles, and systems. In L. Schauble & R. Glaser (Eds.), *Innovations in Learning: New Environments for Education* (pp. 289–325). Hillsdale, NJ, England: Lawrence Erlbaum Associates, Inc.
- Brown, R. (2001). The process of community-building in distance learning classes. *Journal of Asynchronous Learning Networks* 5(2), 18–35. Retrieved July 18, 2015, from

http://spot.pcc.edu/~rsuarez/rbs/school/EPFA_511/articles/from Erica/community building.pdf

- Bryman, A. (2003). *Quantity and Quality in Social Research*. Routledge. Retrieved July 18, 2015, from <https://books.google.com/books?hl=en&lr=&id=jDalAgAAQBAJ&pgis=1>
- Bryman, A. (2006). Integrating quantitative and qualitative research: how is it done? *Qualitative Research*, 6(1), 97–113. doi:10.1177/1468794106058877
- Bryman, A. (2012). *Social Research Methods*. Oxford University Press. Retrieved July 19, 2015, from <https://books.google.com/books?hl=en&lr=&id=vCq5m2hPkOMC&pgis=1>
- Buchanan, E. A., & Hvizdak, E. E. (2009). Online survey tools: ethical and methodological concerns of human research ethics committees. *Journal of Empirical Research on Human Research Ethics* 4(2), 37–48. doi:10.1525/jer.2009.4.2.37
- Burke, M., Marlow, C., & Lento, T. (2009). Feed me: motivating newcomer contribution in social network sites. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 945–954). ACM digital library. doi:10.1145/1518701.1518847
- Burnett, R., Consalvo, M., & Ess, C. (2011). *The Handbook of Internet Studies*. John Wiley & Sons. Retrieved July 7, 2015, from https://books.google.com/books?hl=en&lr=&id=3CakiQW_GVAC&pgis=1
- Butler, B., & Sproull, L. (2002). Community effort in online groups: Who does the work and why. In S. P. Weisband (Eds.), *Leadership at a Distance* (pp. 171–194). NY: Taylor & Francis Group. Retrieved June 24, 2015, from <https://www.google.com/books?hl=en&lr=&id=8haPjnHUKy4C&oi=fnd&pg=PA171&dq=Community+effort+in+online+groups:+Who+does+the+work+and+why%3F&ots=z85-ySexpJ&sig=i1osYyG9X3PnmYU0iZGyZwbmewk>
- Carr, J., Whitelegg, L., Holliman, R., Scanlon, E., & Hodgson, B. (2009). *Investigating Gendered Representations of Scientists, Technologists, Engineers and Mathematicians on UK Children's Television*. Oxford University Press. Retrieved July 16, 2015, from <http://oro.open.ac.uk/13060/>
- Causer, T., & Wallace, V. (2012). Building A Volunteer Community: Results and Findings from Transcribe Bentham. *Digital Humanities Quarterly*, 6(2). Retrieved October 26, 2015, <http://discovery.ucl.ac.uk/1362050/>
- Cavanagh, S. (1997). Content analysis: concepts, methods and applications. *Nurse Researcher*, 4(3), 5–13. Retrieved July 28, 2015, from <http://journals.rcni.com/doi/full/10.7748/nr1997.04.4.3.5.c5869?mobileUi=0>
- Charmaz, K. (2006). *Constructing Grounded Theory: A Practical Guide through Qualitative Analysis (Introducing Qualitative Methods series)*. Sage Publications Ltd. Retrieved July 30, 2015, from <http://www.citeulike.org/group/7276/article/2806115>
- Cherryholmes, C. H. (1992). Notes on pragmatism and scientific realism. *Educational Researcher*, 21(6), 13–17. Retrieved July 30, 2015, from <http://www.jstor.org/stable/1176502>
- Cheung, C. M. K., Lee, M. K. O., & Lee, Z. W. Y. (2013). Understanding the continuance intention of knowledge sharing in online communities of practice through the post-knowledge-sharing

- evaluation processes. *Journal of the American Society for Information Science and Technology*, 64(7), 1357–1374. doi:10.1002/asi.22854
- Chinn, C., & Malhotra, B. (2002). Epistemologically authentic inquiry in schools: A theoretical framework for evaluating inquiry tasks. *Science Education* 86(2), 175–218. doi: 10.1002/sce.10001
- Chiu, C. M., Hsu, M. H., & Wang, E. T. G. (2006). Understanding knowledge sharing in virtual communities: An integration of social capital and social cognitive theories. *Decision Support Systems*, 42(3), 1872–1888. doi:10.1016/j.dss.2006.04.001
- Cialdini, R., & Goldstein, N. (2004). Social influence: Compliance and conformity. *Annual Review of Psychology*, 55, 591–621. doi: 10.1146/annurev.psych.55.090902.142015
- Ciffolilli, A. (2003). Phantom authority, self-selective recruitment and retention of members in virtual communities: The case of Wikipedia. *First Monday*, 8(12). doi:http://dx.doi.org/10.5210/fm.v8i12.1108
- Clarke, A. E. (2003). Situational Analyses: Grounded Theory Mapping After the Postmodern Turn. *Symbolic Interaction*, 26(4), 553–576. doi:10.1525/si.2003.26.4.553
- Clarke, J., Dede, C., Ketelhut, D. J., Nelson, B., & Bowman, C. (2006). A design-based research strategy to promote scalability for educational innovations. *Educational Technology*, 46(3), 27–36.
- Clow, D., & Makriyannis, E. (2011). iSpot analysed: participatory learning and reputation. *Proceedings of the 1st International Conference on Learning Analytics and Knowledge* (pp. 34–43). NY: ACM Digital Library. doi:10.1145/2090116.2090121
- Cobb, P. (2001). Supporting the improvement of learning and teaching in social and institutional context. In S. Carver & D. Klah (Eds.), *Cognition and Instruction: Twenty-five Years of Progress* (pp. 455–478). Cambridge, MA: Lawrence Erlbaum Associates. Retrieved August 1, 2015, from <https://www.google.com/books?hl=en&lr=&id=wYm1vg4LU-wC&oi=fnd&pg=PA455&dq=Supporting++the++improvement++of++learn++ing++and++teaching++in++social++and++institutional++context&ots=0nxniPSLGE&sig=5NCaS6PBohEqxIThg9G63CudN1w>
- Cobb, P., Confrey, J., DiSessa, A., Lehrer, R., & Schauble, L. (2003). Design Experiments in Educational Research. *Educational Researcher*, 32(1), 9–13. doi:10.3102/0013189X032001009
- Cohen, L., Manion, L., & Morrison, K. (2013). *Research Methods in Education*. Oxford: Routledge. Retrieved July 24, 2015, from https://books.google.co.uk/books?hl=en&lr=&id=mLh0Oza3V1IC&oi=fnd&pg=PR3&ots=SNGOHixcql&sig=bJgmh7g6gqKjd_VYL4miCgzjbKU&redir_esc=y#v=onepage&q&f=false
- Collins, A., Joseph, D., & Bielaczyc, K. (2004). Design Research: Theoretical and Methodological Issues. *Journal of the Learning Sciences*, 13(1), 15–42. doi:10.1207/s15327809jls1301_2
- Committee on Science Learning. (2007). *Taking Science to School: Learning and Teaching Science in Grades K-8*. National Academies Press. Retrieved June 14, 2015, from <https://books.google.com/books?hl=en&lr=&id=qMJVAgAAQBAJ&pgis=1>

- Conrad, C. C., & Hilchey, K. G. (2011). A review of citizen science and community-based environmental monitoring: issues and opportunities. *Environmental Monitoring and Assessment*, 176(1), 273–291. doi:10.1007/s10661-010-1582-5
- Constant, D., Kiesler, S., & Sproull, L. (1994). What's mine is ours, or is it? A study of attitudes about information sharing. *Information Systems Research*, 5(4), 400–421. doi:10.1287/isre.5.4.400
- Cooper, S., Khatib, F., Treuille, A., Barbero, J., Lee, J., Beenen, M., ... Popović, Z. (2010). Predicting protein structures with a multiplayer online game. *Nature*, 466(7307), 756–760. doi:10.1038/nature09304
- Cornwall, A., & Jewkes, R. (1995). What is participatory research? *Social Science & Medicine*, 41(12), 1667–1676. doi:10.1016/0277-9536(95)00127-S
- Cothrel, J., & Williams, R. (1999). On-line communities: helping them form and grow. *Journal of Knowledge Management*, 3(1), 54–60. doi: 10.1108/13673279910259394
- Cox, J., Oh, E. Y., Simmons, B., Lintott, C., Masters, K., Greenhill, A., ... Holmes, K. (2015). Defining and Measuring Success in Online Citizen Science: A Case Study of Zooniverse Projects. *Computing in Science & Engineering*, 17(4), 28–41. doi:10.1109/MCSE.2015.65
- Cox, S., & Repede, J. (2013). Information Specificity, Source Expertise and Tie Strength Effects on Word-of-Mouth Effectiveness. *International Journal of Business and Social Science* 4(14), 58–62. Retrieved October 29, 2015, from http://www.ijbssnet.com/journals/Vol_4_No_14_November_2013/8.pdf
- Crall, A. W., Jordan, R., Holfelder, K., Newman, G. J., Graham, J., & Waller, D. M. (2012). The impacts of an invasive species citizen science training program on participant attitudes, behavior, and science literacy. *Public Understanding of Science*, 22(6), 745–764. doi:10.1177/0963662511434894
- Creswell, J. (2009). *Research Design: Qualitative, Quantitative and Mixed Methods Approaches*. Sage. Retrieved June 12, 2015, from http://isites.harvard.edu/fs/docs/icb.topic1334586.files/2003_Creswell_A Framework for Design.pdf
- Cronje, R., Rohlinger, S., Crall, A., & Newman, G. (2010). Does Participation in Citizen Science Improve Scientific Literacy? A Study to Compare Assessment Methods. *Applied Environmental Education and Communication*, 10(3), 135–145. doi:10.1080/1533015X.2011.603611
- Curtis, V. (2015, February 1). *Online citizen science projects: an exploration of motivation, contribution and participation* (Doctoral dissertation, The Open University, UK). Retrieved June 2, 2015, from http://oro.open.ac.uk/42239/1/Vickie_Curtis_PhD_Thesis_Oct_2014.pdf
- Davies, D. L., & Bouldin, D. W. (1979). A Cluster Separation Measure. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, PAMI-1(2), 224–227. doi:10.1109/TPAMI.1979.4766909
- de Jong, T. (2014). The Guided Discovery Principle in Multimedia Learning. In R. Mayer (Eds.), *The Cambridge Handbook of Multimedia Learning* (pp. 371–390). Cambridge: Cambridge University Press. doi:http://dx.doi.org/10.1017/CBO9781139547369.019

- Citizen Science Central. (2015). Defining Citizen Science. Retrieved June 2, 2015, from <http://www.birds.cornell.edu/citscitoolkit/about/definition>
- Denise, F., Beck, C., & Hungler, B. P. . (2001). *Essentials of Nursing Research: Methods, Appraisal, and Utilization*. Lippincott. Retrieved July 6, 2015, from <http://www.philadelphia.edu.jo/newlibrary/pdf/filee02a0b1218684cd6af763d53b456522f.pdf>
- Design-Based Research Collective. (2003). Design-Based Research: An Emerging Paradigm for Educational Inquiry. *Educational Researcher*, 32(1), 5–8. Retrieved July 1, 2015, from http://www.jstor.org/stable/3699927?seq=1#page_scan_tab_contents
- Dewey, J. (1910). Science as subject-matter and as method. *Science* 31(787), 121–127. Retrieved June 9, 2015, from <http://www.jstor.org/stable/1634781>
- Dewey, J. (1933). *How we Think: A Restatement of the Relation of Reflective Thinking to the Educational Process*. Lexington, MA: Heath. Retrieved June 9, 2015, from https://scholar.google.gr/scholar?hl=en&q=How+we+think%3A+A+restatement+of+the+relation+of+reflective+thinking+to+the+educative+process&btnG=&as_sdt=1%2C5&as_sdtp=#0
- Diamond, I. (2006). *Science Education in Schools – Issues, Evidence, and Proposals* (The Association for Science Education report). Retrieved June 17, 2015, from http://www.tlrp.org/pub/documents/TLRP_Science_Commentary_FINAL.pdf
- Dichter, E. (1966). How word-of-mouth advertising works. *Harvard Business Review*, 6(44), 147–160. Retrieved October 6, 2015, from <http://www.citeulike.org/group/328/article/1580011>
- Doan, A., Ramakrishnan, R., & Halevy, A. Y. (2011). Crowdsourcing systems on the World-Wide Web. *Communications of the ACM*, 54(4), 86. doi:10.1145/1924421.1924442
- Downes, S. (2010). Learning Networks and Connective Knowledge. In H. H. Yang (Ed.), *Collective Intelligence and Elearning* (pp. 1–26). Retrieved from <http://philpapers.org/rec/DOWLNA>
- Druschke, C. G., & Seltzer, C. E. (2012). Failures of Engagement: Lessons Learned from a Citizen Science Pilot Study. *Applied Environmental Education & Communication*, 11(3-4), 178–188. doi:10.1080/1533015X.2012.777224
- Duke, M., Tonkin, E., & web-support@bath.ac.uk. (2012, September 1). *Patients Participate! Literature Review: Usability and Human Factors in Citizen Science Projects, and Trust and Credibility on the Web*. University of Bath. Retrieved June 30, 2015, from http://opus.bath.ac.uk/33730/1/PatientsParticipate_literature_review_v1.2.pdf
- Edelson, D. C. (2002). Design Research: What We Learn When We Engage in Design. *Journal of the Learning Sciences*, 11(1), 105–121. doi:10.1207/S15327809JLS1101_4
- Edelson, D. C., Gordin, D. N., & Pea, R. D. (1999). Addressing the challenges of inquiry-based learning through technology and curriculum design. *Journal of the Learning Sciences*, 8(3-4), 391–450. doi:10.1080/10508406.1999.9672075
- Edwards, R. (2014). The “Citizens” in Citizen Science Projects: Educational and Conceptual Issues. *International Journal of Science Education, Part B*. Retrieved from <http://www.tandfonline.com/doi/full/10.1080/21548455.2014.953228>

- Ellis, R., & Waterton, C. (2004). Environmental citizenship in the making: the participation of volunteer naturalists in UK biological recording and biodiversity policy. *Science and Public Policy*. Retrieved from <http://spp.oxfordjournals.org/content/31/2/95.short>
- Ellison, N. B., Steinfield, C., & Lampe, C. (2007). The Benefits of Facebook "Friends:" Social Capital and College Students' Use of Online Social Network Sites. *Journal of Computer-Mediated Communication*, 12(4), 1143–1168. doi:10.1111/j.1083-6101.2007.00367.x
- Elo, S., & Kyngäs, H. (2008). The qualitative content analysis process. *Journal of Advanced Nursing*, 62(1), 107–15. doi:10.1111/j.1365-2648.2007.04569.x
- Emanuel, L., Neil, G. J., Bevan, C., Fraser, D. S., Stevenage, S. V., Whitty, M. T., & Jamison-Powell, S. (2014). Who am I? Representing the self offline and in different online contexts. *Computers in Human Behavior*, 41, 146–152. doi:10.1016/j.chb.2014.09.018
- Engeström, Y., Engeström, R., & Suntio, A. (2002). Can a school community learn to master its own future? An activity-theoretical study of expansive learning among middle school teachers. In G. Wells & G. Claxton (Eds.), *Learning for Life in the 21st Century: Sociocultural Perspectives on the Future of Education*. Oxford: Blackwell Publishing Ltd. doi:10.1002/9780470753545.ch16
- Evans, R., & Collins, H. (2007). Expertise: From attribute to attribution and back again. In E. J. Hackett, O. Amsterdamska, M. Lynch, & J. Wajcman (Eds.), *The Handbook of Science & Technology Studies* (pp. 609–630). Cambridge, MA: The MIT press. Retrieved July 6, 2015, from https://scholar.google.gr/scholar?q=Expertise%3A+From+attribute+to+attribution+and+back+again%3F&btnG=&hl=en&as_sdt=0%2C5#0
- Eveleigh, A., Jennett, C., Blandford, A., Brohan, P., & Cox, A. L. (2014). Designing for dabblers and deterring drop-outs in citizen science. In *Proceedings of the 32nd Annual ACM Conference on Human Factors in Computing Systems – CHI '14* (pp. 2985–2994). New York: ACM Press. doi:10.1145/2556288.2557262
- EveryAware Project. (2012). *EveryAware at CeBIT 2014*. Retrieved November 20, 2015, from <http://www.everyaware.eu/>
- Fiedler, M., & Sarstedt, M. (2014). Influence of community design on user behaviors in online communities. *Journal of Business Research*, 67(11), 2258–2268. doi:10.1016/j.jbusres.2014.06.014
- Fielding, N., Lee, R., & Blank, G. (2008). *The Sage Handbook of Online Research Methods*. Sage. Retrieved June 24, 2015, from <https://books.google.co.uk/books?hl=en&lr=&id=EeMKURpicCgC&oi=fnd&pg=PP1&dq=The+SAGE+Handbook+of+Online+Research+Methods&ots=3yPZsdy451&sig=EdxcEoG3kOkIP92TfDxgzpAtA44>
- Fischer, G. (2002). Beyond "couch potatoes": From consumers to designers and active contributors. *Proceedings of Computer Human Interaction 3rd Asia Pacific* (pp. 2–9). IEEE. doi:10.1109/APCHI.1998.704130
- Flick, U. (2009). *An Introduction to Qualitative Research*. SAGE Publications. Retrieved June 17, 2015, from <https://books.google.com/books?hl=en&lr=&id=PQRdBAABQBAJ&pgis=1>

- Fogg, B., Soohoo, C., & Danielson, D. (2003). How do users evaluate the credibility of Web sites?: a study with over 2,500 participants. *Proceedings of the 2003 Conference on Designing for User Experiences* (pp. 1–15). doi:10.1145/997078.997097
- Förstner, K., Koltzenburg, G., & Fabiana, M., Kubke, M. F., & Mietchen, D. (2011). Collaborative platforms for streamlining workflows in Open Science. *Proceedings of the 6th Open Knowledge Conference*. Nature Precedings. doi:10.1038/npre.2011.6066.1
- Fortson, L., Masters, K., Nichol, R., Borne, K., Edmondson, E., Lintott, C., ... Wallin, J. (2011). Galaxy Zoo: Morphological classification and citizen science. In M. J. Way, J. D. Scargle, K. M. Ali, & A. N. Srivastava (Eds.), *Advances in Machine Learning and Data Mining for Astronomy* (pp. 213-236). Boca Raton, FL: CRC Press. Retrieved June 9, 2015, from https://books.google.co.uk/books?hl=en&lr=&id=YafMBQAAQBAJ&oi=fnd&pg=PA213&ots=f n8HhbCRjn&sig=wGiFWC48sU5FreOePS9ufYkCT8c&redir_esc=y#v=onepage&q&f=false
- Fossil Finders. (2015). *What is Fossil Finders?* Retrieved August 3, 2015, from <http://fossilfinder.coe.uga.edu/about/what-is-fossil-finders/>
- Freitag, A., & Pfeffer, M. (2013). Process, not product: investigating recommendations for improving citizen science “success.” *PLoS ONE*, 8(5), e64079. doi:10.1371/journal.pone.0064079
- Friedman, A. (2008). *Framework for Evaluating Impacts of Informal Science Education Projects* (Report from a National Science Foundation workshop). Retrieved June 13, 2015, from http://www.aura-astronomy.org/news/EPO/eval_framework.pdf
- Galloway, A. W. E., Tudor, M. T., Haegen, W., & Vander, M. (2006). The reliability of citizen science: a case study of Oregon white oak stand surveys. *Wildlife Society Bulletin*, 34(5), 1425–1429. doi: 10.2193/0091-7648(2006)34[1425:TROCSA]2.0.CO;2
- Garrison, D. (2011). *E-learning in the 21st Century: A Framework for Research and Practice*. New York, NY: Routledge. Retrieved July 6, 2015, from <https://www.google.com/books?hl=en&lr=&id=aodjWyjxYbYC&oi=fnd&pg=PP1&dq=garrison+2011+community+of+inquiry&ots=-zmDtPRnS-&sig=1Jw3XchCnqSSauOHKhdfTvSEPRU>
- Garrison, D. R., & Arbaugh, J. B. (2007). Researching the Community of Inquiry Framework: Review, Issues, and Future Directions. *Internet and Higher Education*, 10, 157–172. doi:10.1016/j.iheduc.2007.04.001
- Garrison, R. D. (2007). Online Community of Inquiry Review: Social, Cognitive, and Teaching Presence Issues. *Journal of Asynchronous Learning Networks*, 11(1), 61–72. Retrieved June 29, 2015, from <http://eric.ed.gov/?id=EJ842688>
- Gertz, M. (2002). Data annotation in collaborative research environments. *Workshop on Data Derivation and Provenance*. Retrieved November 7, 2015, from <http://www.ipaw.info/chicago02/papers/gertz-position-paper.pdf>
- Ghosh, R. (2005). Understanding free software developers: Findings from the FLOSS study. Paper presented at the Conference of New Models of Software Development, Harvard Business School. Retrieved July 17, 2015, from <http://www.flossproject.org/papers/ghosh-2005.pdf>
- Ginsburg, M., & Weisband, S. (2004). A framework for virtual community business success: The

- case of the internet chess club. *Proceedings of the 37th Annual Hawaii International Conference on System Sciences*, 7, (pp. 70196–2). Washington, DC: IEEE. doi: 10.1109/HICSS.2004.1265466
- Glaser, B. (1978). *Theoretical Sensitivity: Advances in the Methodology of Grounded Theory*. CA: Sociology Press. Retrieved from https://scholar.google.gr/scholar?q=Theoretical+Sensitivity%3A++Advances+in+the+Methodology+of+Grounded+Theory.&btnG=&hl=en&as_sdt=0%2C5#0
- Godwin, S., & McAndrew, P. (2008, January 27). Exploring user types and what users seek in an open content based educational resource. *Proceedings of ED-MEDIA 2008 World Conference on Educational Multimedia, Hypermedia and Telecommunications* (pp. 3711–3718). Association for the Advancement of Computing in Education (AACE). Retrieved July, 20, 2015, from <http://www.editlib.org/p/28900>
- Graneheim, U. H., & Lundman, B. (2004). Qualitative content analysis in nursing research: concepts, procedures and measures to achieve trustworthiness. *Nurse Education Today*, 24(2), 105–12. doi:10.1016/j.nedt.2003.10.001
- Gray, B. (2003). Informal Learning in an Online Community of Practice. *Journal of Distance Education*, 19(1), 20–35. Retrieved June 28, 2015, from <http://eric.ed.gov/?id=EJ807836>
- Grey, F. (2009, April 29). Viewpoint: The age of citizen cyberscience [Web log post]. Retrieved July 29, 2015, from <http://cerncourier.com/cws/article/cern/38718>
- Guba, E. (1981). Criteria for assessing the trustworthiness of naturalistic inquiries. *ECTJ*, 29(2), 75–91. doi: 10.1007/BF02766777
- Guest, G., MacQueen, K., & Namey, E. (2011). *Applied Thematic Analysis*. Sage. Retrieved June 20, 2015, from https://scholar.google.gr/scholar?q=Applied+thematic+analysis&btnG=&hl=en&as_sdt=0%2C5#0
- Haklay, M. (2011). Classification of Citizen Science activities [Web log post]. Retrieved June 4, 2015, from <https://povesham.wordpress.com/2011/07/20/classification-of-citizen-science-activities/>
- Haklay, M. (2013). Citizen science and volunteered geographic information: Overview and typology of participation. In D. Sui, S. Elwood, & M. Goodchild (Eds.), *Crowdsourcing Geographic Knowledge* (pp. 105-122). doi: 10.1007/978-94-007-4587-2_7
- Hand, E. (2010). Citizen science: People power. *Nature*, 466(7307), 685–687. doi:10.1038/466685a
- Hanington, B., & Martin, B. (2012). *Universal Methods of Design: 100 Ways to Research Complex Problems, Develop Innovative Ideas, and Design Effective Solutions*. Rockport Publishers. Retrieved August 3, 2015, from <https://books.google.com/books?hl=en&lr=&id=pCVATlpzYfUC&pgis=1>
- Haythornthwaite, C. (2009). Crowds and Communities: Light and Heavyweight Models of Peer Production. In *2009 42nd Hawaii International Conference on System Sciences* (pp. 1–10). IEEE. doi:10.1109/HICSS.2009.137

- Haythornthwaite, C., & Laat, M. De. (2010). Social networks and learning networks: Using social network perspectives to understand social learning. *7th International Conference on Networked Learning* (pp. 183–190). Aalborg, Denmark: Lancaster University. Retrieved August 4, 2015, from http://celstec.org.uk/system/files/file/conference_proceedings/NLC2010_Proceedings/abstracts/PDFs/Haythornwaite.pdf
- Heijden, H. Van der. (2003). Factors influencing the usage of websites: the case of a generic portal in The Netherlands. *Information & Management*, 40(6), 541–549. doi: 10.1016/S0378-7206(02)00079-4
- Hemminki, S., Nurmi, P., & Tarkoma, S. (2014). Gravity and linear acceleration estimation on mobile devices. In *Proceedings of the 11th International Conference on Mobile and Ubiquitous Systems: Computing, Networking and Services* (pp. 50–59). ICST (Institute for Computer Science, Social-Informatics and Telecommunications Engineering).
- Heritage, J. (2013). *Garfinkel and Ethnomethodology*. John Wiley & Sons. Retrieved June 13, 2015, from <https://books.google.com/books?hl=en&lr=&id=sRoNAAAQBAJ&pgis=1>
- Herodotou, C., Villasclaras-Fernandez, E., & Sharples, M. (2014). Scaffolding citizen inquiry science learning through the nQuire toolkit. In *Proceedings of EARLI SIG 20: Computer Supported Inquiry Learning* (pp. 9–11). Retrieved July 9, 2015, from http://oro.open.ac.uk/42030/1/EARLIsig20meeting_submission_3_final%281%29.pdf
- Herodotou, C., Winters, N., & Kambouri, M. (2012). A Motivationally Oriented Approach to Understanding Game Appropriation. *International Journal of Human-Computer Interaction*, 28(1), 34–47. doi:10.1080/10447318.2011.566108
- Hoadley, C. M. (2004). Methodological Alignment in Design-Based Research. *Educational Psychologist*, 39(4), 203–212. doi:10.1207/s15326985ep3904_2
- Holliman, R., & Curtis, V. (2014). Online media. In R. Gunstone (Ed.), *Encyclopedia of Science Education* (pp. 1–8). Springer Netherlands. doi:10.1007/978-94-007-6165-0_53-3
- Holohan, A., & Garg, A. (2005). Collaboration online: The example of distributed computing. *Journal of Computer-Mediated Communication*, 10(4). doi:10.1111/j.1083-6101.2005.tb00279.x
- Howe, J. (2006). The rise of crowdsourcing. *Wired Magazine*, 14(6), 1–4. Retrieved July 19, 2015, from http://sistemas-humano-computacionais.wikidot.com/local--files/capitulo:redes-sociais/Howe_The_Rise_of_Crowdsourcing.pdf
- Ipsos MORI. (2011). *Public Attitudes to Science 2011* (Report). London: Department for Business Innovation and Skills. Retrieved June 1, 2015, from https://scholar.google.gr/scholar?q=Public+Attitudes+to+Science+2011&btnG=&hl=en&as_sdt=0%2C5#0
- Ipsos MORI. (2014). *Public Attitudes to Science 2014* (Report). London: Department for Business Innovation and Skills. Retrieved June 1, 2015, from <https://www.ipsos-mori.com/Assets/Docs/Polls/pas-2014-main-report.pdf>
- Iriberry, A., & Leroy, G. (2009). A life-cycle perspective on online community success. *ACM*

- Computing Surveys (CSUR)*, 41(2), article no. 11. New York, NY: ACM Digital Library.
doi:10.1145/1459352.1459356
- Ivankova, N. V., Creswell, J., & Stick, S. (2006). Using Mixed-Methods Sequential Explanatory Design: From Theory to Practice. *Field Methods*, 18(1), 3–20.
doi:10.1177/1525822X05282260
- Jamali, H., Russell, B., Nicholas, D., & Watkinson, A. (2014). Do online communities support research collaboration? *Aslib Journal of Information Management*, 66(6), 603–622.
doi:10.1108/AJIM-08-2013-0072
- Jan, M., Chee, Y. S., & Tan, E. M. (2010). Unpacking the design process in design-based research. *Proceedings of the 9th International Conference of the Learning Sciences ICLS '10*, 2 (pp. 470–471). Retrieved August 6, 2015, from <http://dl.acm.org/citation.cfm?id=1854509.1854751>
- Jennett, C., & Cox, A. L. (2014, October 14). *Eight Guidelines for Designing Virtual Citizen Science Projects*. Paper presented at the Second AAAI Conference on Human Computation and Crowdsourcing. Retrieved October 30, 2015, from <http://www.aaai.org/ocs/index.php/HCOMP/HCOMP14/paper/view/9261>
- Jennett, C., Eveleigh, A., Mathieu, K., Ajani, Z., & Cox, A. (2013, June 5). *Creativity in citizen science: All for one and one for all*. Paper presented at the ACM Web Science Conference, Websci'13. Retrieved August 5, 2015, from <http://discovery.ucl.ac.uk/1395531/>
- Johnson, R. B., & Onwuegbuzie, A. J. (2004). Mixed Methods Research: A Research Paradigm Whose Time Has Come. *Educational Researcher*, 33(7), 14–26.
doi:10.3102/0013189X033007014
- Jordan, R. C., Ballard, H. L., & Phillips, T. B. (2012). Key issues and new approaches for evaluating citizen-science learning outcomes. *Frontiers in Ecology and the Environment*, 10(6), 307–309.
doi:10.1890/110280
- Jordan, R. C., Gray, S. A., Howe, D. V., Brooks, W. R., & Ehrenfeld, J. G. (2011). Knowledge Gain and Behavioral Change in Citizen-Science Programs. *Conservation Biology*, 25(6), 1148–1154.
doi:10.1111/j.1523-1739.2011.01745.x
- Jordan, R., Crall, A., & Gray, S. (2015). Citizen Science as a Distinct Field of Inquiry. *BioScience*, 65(2), 208–211. doi:10.1093/biosci/biu217
- Jordan, R., Gray, S., & Howe, D. (2011). Knowledge gain and behavioral change in citizen-science programs. *Conservation biology*, 25(6), 1148–1154. doi:10.1111/j.1523-1739.2011.01745.x
- Kaplan, A. M., & Haenlein, M. (2010). Users of the world, unite! The challenges and opportunities of Social Media. *Business Horizons*, 53(1), 59–68. doi:10.1016/j.bushor.2009.09.003
- Kawrykow, A., Roumanis, G., Kam, A., Kwak, D., Leung, C., Wu, C., ... Waldispuhl, J. (2012). Phylo: a citizen science approach for improving multiple sequence alignment. *PLoS One*, 7, e31362.
doi:10.1371/journal.pone.0031362
- Kim, A. (2000). *Community Building on the Web: Secret Strategies for Successful Online Communities*. Boston, MA: Addison-Wesley Longman Publishing Co., Inc. Retrieved July 13, 2015, from <http://dl.acm.org/citation.cfm?id=518514>

- Kim, S., Robson, C., Zimmerman, T., Pierce, J., & Haber, E. M. (2011). Creek watch. In *Proceedings of the 2011 Annual Conference on Human factors in Computing Systems - CHI '11* (pp. 2125–2134). New York, USA: ACM Press. doi:10.1145/1978942.1979251
- Kittur, A., & Kraut, R. E. (2008). Harnessing the wisdom of crowds in wikipedia. In *Proceedings of the ACM 2008 Conference on Computer Supported Cooperative Work - CSCW '08* (pp. 37–46). New York, USA: ACM Press. doi:10.1145/1460563.1460572
- Kloetzer, L., Schneider, D., Jennett, C., Iacovides, I., Eveleigh, A., Cox, A., & Gold, M. (2013). Learning by volunteer computing, thinking and gaming: What and how are volunteers learning by participating in Virtual Citizen Science? In B. Kapplinger, N. Lichte, E. Haberzeth, & C. Kulmus (Eds.), *Changing Configurations of Adult Education in Transitional Times, Proceedings of 7th European Research Conference - ESREA* (pp. 73–92). Retrieved June 13, 2015, from <http://discovery.ucl.ac.uk/1418570/>
- Kondracki, N. L., Wellman, N. S., & Amundson, D. R. (2002). Content Analysis: Review of Methods and their Applications in Nutrition Education. *Journal of Nutrition Education and Behavior*, 34(4), 224–230. doi:10.1016/S1499-4046(06)60097-3
- Kraut, R. E., Burke, M., Riedl, J., & Resnick, P. (2012). The challenges of dealing with newcomers. In R. E. Kraut, & P. Resnick (Eds.), *Building Successful Online Communities: Evidence-based Social Design* (pp. 179–230). MIT Press. Retrieved July 25, 2015, from <https://books.google.com/books?hl=en&lr=&id=llvBMVvXWJYC&pgis=1>
- Kraut, R. E., Resnick, P., Kiesler, S., Burke, M., Chen, Y., Kittur, N., ... Riedl, J. (2012). *Building Successful Online Communities: Evidence-Based Social Design* (Google eBook). MIT Press. Retrieved July 25, 2015, from <http://books.google.com/books?hl=en&lr=&id=llvBMVvXWJYC&pgis=1>
- Kraut, R., & Resnick, P. (2011). *Evidence-based Social Design: Mining the Social Sciences to Build Successful Online Communities*. Cambridge, MA: MIT press. Retrieved from https://scholar.google.gr/scholar?q=Evidence-based+social+design%3A+Mining+the+social+sciences+to+build+successful+online+communities&btnG=&hl=en&as_sdt=0%2C5#0
- Kroenke, D. (2014). *e-Study Guide for: Database Concepts*. Cram101 Textbook Reviews. Retrieved December 1, 2015, from <https://books.google.com/books?id=qVvaAwAAQBAJ&pgis=1>
- Kubey, R., & Csikszentmihalyi, M. (2013). *Television and the Quality of Life: How Viewing Shapes Everyday Experience*. New York, NY: Routledge. Retrieved August 7, 2015, from <https://www.google.com/books?hl=en&lr=&id=3g1EAgAAQBAJ&oi=fnd&pg=PP1&dq=Television+and+the+quality+of+life:+How+viewing+shapes+everyday+experience.+&ots=WcR10LYgG3&sig=VY5TTxtBceOXRBPj62gPHJZeTE>
- Lakhani, K., & Wolf, R. (2003). Why hackers do what they do: Understanding motivation and effort in free/open source software projects (MIT Sloan Working Paper No. 4425-03). Retrieved July 27, 2015, from Sloan School of Management database: http://papers.ssrn.com/sol3/Papers.cfm?abstract_id=443040
- Lakshminarayanan, S. (2007). Using citizens to do science versus citizens as scientists. *Ecology and Society*, 12(2), 2. Retrieved June 29, 2015, from

- Lave, J., & Wenger, E. (1991). *Situated Learning: Legitimate Peripheral Participation*. Cambridge University Press. doi:10.2307/2804509
- Lehmann, J., Lalmas, M., Yom-Tov, E., & Dupret, G. (2012). Models of user engagement. In J. Masthoff, B. Mobasher, M.C. Desmarais, & R. Nkambou (Eds.), *User Modeling, Adaptation, and Personalization, 7379*, 164–175. doi:10.1007/978-3-642-31454-4_14
- Leimeister, J., Ebner, W., & Krcmar, H. (2005). Design, implementation, and evaluation of trust-supporting components in virtual communities for patients. *Journal of Management Information Systems, 21*(4), 103–131. doi:10.1080/07421222.2005.11045825
- Libbrecht, K. (2004). Snowflake science. *American Educator*, Winter, 20–25. Retrieved October 5, 2015, from https://scholar.google.gr/scholar?hl=en&q=snowflake+science&btnG=&as_sdt=1%2C5&as_sdtp=#0
- Lin, N. (1976). *Foundations of Social Research*. New York: McGraw-Hill. Retrieved June 13, 2015, from <http://library.wur.nl/WebQuery/clc/330850>
- Ling, K., Beenen, G., & Ludford, P. (2005). Using social psychology to motivate contributions to online communities. *Journal of Computer-mediated Communication, 10*(4). doi:10.1111/j.1083-6101.2005.tb00273.x
- Linn, M. C., & Slotta, J. D. (2013). Enabling Participants in Online Forums to Learn From Each Other. In A. M. O'Donnell, C. E. Hmelo-Silver, & G. Erkens (Eds.), *Collaborative Learning, Reasoning, and Technology* (pp. 61–98). Routledge. Retrieved July 14, 2015, from <https://books.google.com/books?hl=en&lr=&id=Ma7lIRWbOG0C&pgis=1>
- Littleton, K., & Kerawalla, L. (2012). Trajectories of Inquiry Learning. In K. Littleton, E. Scanlon, & M. Sharples (Eds.), *Orchestrating Inquiry Learning* (pp. 31–47). Abingdon, England. Retrieved June 2, 2015, from <http://oro.open.ac.uk/30255/>
- Littleton, K., Scanlon, E., & Sharples, M. (2012). *Orchestrating Inquiry Learning*. Abingdon, England: Routledge. Retrieved June 2, 2015, from <https://www.google.com/books?hl=en&lr=&id=zNvFBQAAQBAJ&oi=fnd&pg=PT8&dq=orchestrating+inquiry+learning&ots=Xs4RvEgL3w&sig=kXjAiprKJPRsOsmW8mngjJalTrM>
- Liu, J., & Ram, S. (2011). Who does what: Collaboration patterns in the wikipedia and their impact on article quality. *ACM Transactions on Management Information Systems, 2*(2), 1–23. Retrieved July 25, 2015, from <http://dl.acm.org/citation.cfm?id=1985352>
- Lloyd, R., Neilson, R., King, S., & Dyball, M. (2012). *Review of Informal Science Learning: Executive Summary*. London. Retrieved from http://www.wellcome.ac.uk/stellent/groups/corporatesite/@msh_peda/documents/web_document/wtp040863.pdf
- Locke, E., & Latham, G. (2002). Building a practically useful theory of goal setting and task motivation: A 35-year odyssey. *American Psychologist, 57*(9), 705–717. doi: 10.1037/0003-066X.57.9.705
- Lu, J. F., Tang, J. B., Tang, Z. M., & Yang, J. Y. (2008). Hierarchical initialization approach for K-

- Means clustering. *Pattern Recognition Letters*, 29(6), 787–795.
doi:10.1016/j.patrec.2007.12.009
- Luczak-Roesch, M., Tinati, R., & Simperl, E. (2014). Why won't aliens talk to us? Content and community dynamics in online citizen science. *Proceedings of the Eighth International AAAI Conference on Weblogs and Social Media* (pp. 315–324). Retrieved June 24, 2015, from <http://eprints.soton.ac.uk/363523/>
- Maisonneuve, N., Stevens, M., Niessen, M. E., & Steels, L. (2009). NoiseTube: Measuring and mapping noise pollution with mobile phones. In I. N. Athanasiadis, A. E. Rizzoli, P. A. Mitkas, & J. M. Gómez (Eds.), *Proceedings of the 4th International ICSC Symposium* (pp. 215–228). Berlin, Heidelberg: Springer Berlin Heidelberg. doi:10.1007/978-3-540-88351-7
- Malhotra, A., Gosain, S., & Hars, A. (1997). Evolution of a virtual community: Understanding design issues through a longitudinal study. *Proceedings of the Eighteenth International Conference on Information Systems – ICIS* (pp. 59–73). Retrieved June 30, 2015, from <http://dl.acm.org/citation.cfm?id=353089>
- Malinen, S. (2015). Understanding user participation in online communities: A systematic literature review of empirical studies. *Computers in Human Behavior*, 46, 228–238.
doi:10.1016/j.chb.2015.01.004
- Maloney-Krichmar, D., & Preece, J. (2005). A multilevel analysis of sociability, usability, and community dynamics in an online health community. *ACM Transactions on Computer-Human Interaction*, 12(2), 201–232. Retrieved July 4, 2015, from <http://dl.acm.org/citation.cfm?id=1067864>
- Mason, A. D., Michalakidis, G., & Krause, P. J. (2012). Tiger Nation: Empowering citizen scientists. *IEEE International Conference on Digital Ecosystems and Technologies* (pp. 1–5). IEEE.
doi:10.1109/DEST.2012.6227943
- Mason, R. (1994). *Using Communications Media in Open and Flexible Learning*. London: Korgan Page. Retrieved August 5, 2015, from https://www.google.com/books?hl=en&lr=&id=RrA_1gqFkwcC&oi=fnd&pg=PP2&dq=Using+communications+media+in+open+and+flexible+learning.+&ots=DtE7qt9Shl&sig=w5SexShtjvDIOUGRKKjHB5i0U9w
- Maxwell, J. (2012). *Qualitative Research Design: An Interactive Approach*. Sage. Retrieved June 14, 2015, from https://scholar.google.com/scholar?q=Qualitative+Research+Design&btnG=&hl=en&as_sdt=0%2C5#2
- Mayring, P. (2000, June 30). Qualitative Content Analysis. *Forum Qualitative Sozialforschung / Forum: Qualitative Social Research*, 1(2), article no. 20. Retrieved June 24, 2015, from <http://www.qualitative-research.net/index.php/fqs/article/view/1089/2385>
- McCallie, E., Bell, L., Lohwater, T., Falk, J. H., Lehr, J. L., Lewenstein, B. V., ... Wiehe, B. (2009). *Many Experts, Many Audiences: Public Engagement with Science and Informal Science Education* (A CAISE Inquiry Group Report. Executive Summary). Center for Advancement of Informal Science Education. Retrieved June 1, 2015, from ERIC database: <http://eric.ed.gov/?id=ED536432>

- McCann, K. (2009). Virtual Communities for Educators: An Overview of Supports and Best Practices. In *TCC Worldwide Online Conference* (pp. 137–142). TCC Hawaii. Retrieved July 9, 2015, from <http://etec.hawaii.edu/proceedings/2009/McCann.pdf>
- McKenna, K. Y. A., & Bargh, J. A. (2000). Plan 9 From Cyberspace: The Implications of the Internet for Personality and Social Psychology. *Personality and Social Psychology Review*, 4(1), 57–75. doi:10.1207/S15327957PSPR0401_6
- McKenna, K. Y., Green, A., & Gleason, M. E. (2002). Relationship formation on the Internet: What's the big attraction? *Journal of Social Issues*, 58(1), 9–31. doi:10.1111/1540-4560.00246
- McWilliam, G. (2012). Building stronger brands through online communities. *Sloan Management Review*, 41(3), 43–54. Retrieved August 2, 2015, from <http://sloanreview.mit.edu/article/building-stronger-brands-through-online-communities/>
- Merriam, S. B., Caffarella, R. S., & Baumgartner, L. M. (2012). *Learning in Adulthood: A Comprehensive Guide*. John Wiley & Sons. Retrieved July 31, 2015, from <https://books.google.com/books?hl=en&lr=&id=ffaKVcPVC84C&pgis=1>
- Merton, R., Fisk, M., & Kendall, P. (1956). *The Focused Interview: a Report of the Bureau of Applied Social Research*. New York: Columbia University. Retrieved June 20, 2015, from https://scholar.google.com/scholar?hl=en&as_sdt=0,5&cluster=8811477336041287284#0
- Meyer, J., & Allen, N. (1991). A three-component conceptualization of organizational commitment. *Human Resource Management Review*, 1(1), 61–89. doi:10.1016/1053-4822(91)90011-Z
- Michaels, S., Shouse, A., & Schweingruber, H. (2008). *Ready, Set, Science. Putting Research to Work in K-8 Science Classrooms*. Washington, DC: National Academies Press. Retrieved from https://scholar.google.gr/scholar?q=Ready%2C+set%2C+science&btnG=&hl=en&as_sdt=0%2C5#1
- Michinov, N. (2004). Social Identity, Group Processes, and Performance in Synchronous Computer-Mediated Communication. *Group Dynamics: Theory, Research, and Practice*, 8(1), 27. doi: 10.1037/1089-2699.8.1.27
- Morgan, D. (1993). Qualitative content analysis: A guide to paths not taken. *Qualitative Health Research*, 3(1), 112–121. Retrieved June 20, 2015 from https://scholar.google.com/scholar?oi=bibs&hl=en&cites=9375737419731862339&as_sdt=5#0
- Morgan, D. (1997). *The Focus Group Guidebook*. Sage Publications, Inc. Retrieved 21 June, 2015, from <https://www.google.com/books?hl=en&lr=&id=Wkl2AwAAQBAJ&oi=fnd&pg=PP1&ots=XuNZ96Kjv0&sig=sEppivCdJWXgCK0CqNv-xB08kEA>
- Morse, J. (1991). Approaches to qualitative-quantitative methodological triangulation. *Nursing Research*, 40(2), 120–123. Retrieved June 20, 2015, from http://journals.lww.com/nursingresearchonline/Abstract/1991/03000/Approaches_to_Qualitative_Quantitative.14.aspx

- Mueller, M., & Tippins, D. (2012). The future of citizen science. *Democracy and Education*, 20(1), article no. 2. Retrieved June 6, 2015, from <http://democracyeducationjournal.org/home/vol20/iss1/2/>
- Mugar, G., Østerlund, C., Hassman, K. D., Crowston, K., & Jackson, C. B. (2014). Planet hunters and seafloor explorers. In *Proceedings of the 17th ACM conference on Computer Supported Cooperative Work & Social Computing - CSCW '14* (pp. 109–119). New York, USA: ACM Press. doi:10.1145/2531602.2531721
- Mulholland, P., Anastopoulou, S., Collins, T., Feisst, M., Gaved, M., Kerawalla, L., ... Wright, M. (2012). nQuire: Technological Support for Personal Inquiry Learning. *IEEE Transactions on Learning Technologies*, 5(2), 157–169. doi:10.1109/TLT.2011.32
- National Research Council. (1996). *National Science Education Standards*. Washington, DC: National Academies Press. Retrieved June 15, 2015, from https://scholar.google.gr/scholar?hl=en&q=National+Science+Education+Standards.&btnG=&as_sdt=1%2C5&as_sdt=0
- Newman, J. C., Des Jarlais, D. C., Turner, C. F., Gribble, J., Cooley, P., & Paone, D. (2002). The Differential Effects of Face-to-Face and Computer Interview Modes. *American Journal of Public Health*, 92(2), 294–297. doi:10.2105/AJPH.92.2.294
- Nielsen, J. (2006, October 9). Participation Inequality: The 90-9-1 Rule for Social Features [Web log post]. Retrieved June 5, 2015, from <http://www.nngroup.com/articles/participation-inequality/>
- Nonnecke, B., & Preece, J. (2000). Lurker demographics: Counting the silent. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 73-80). ACM. doi:10.1145/332040.332409
- Norusis, M. (2007). *SPSS 15.0 guide to Data Analysis*. Englewood Cliffs, NJ: Prentice Hall. Retrieved October 13, 2015, from http://dissertation.argosy.edu/chicago/spring08/pp7202_sp08canar.doc
- Nov, O. (2007). What motivates Wikipedians? *Communications of the ACM*, 50(11), 60–64. doi:10.1145/1297797.1297798
- Nov, O., Arazy, O., & Anderson, D. (2011). Dusting for science: motivation and participation of digital citizen science volunteers. In *Proceedings of the 2011 iConference* (pp. 68–74). ACM. doi:10.1145/1940761.1940771
- Nowak, M., & Sigmund, K. (2005). Evolution of indirect reciprocity. *Nature*, 437, 1291–1298. doi:10.1038/nature04131
- O'Brien, H., & Toms, E. (2008). What is user engagement? A conceptual framework for defining user engagement with technology. *Journal of the American Society for Information Science and Technology*, 59(6), 938–955. doi:10.1002/asi.20801
- Oberhauser, K., & LeBuhn, G. (2012). Insects and plants: engaging undergraduates in authentic research through citizen science. *Frontiers in Ecology and the Environment*, 10(6), 318–320. doi:10.1890/110274
- Oh, S. (2012). The characteristics and motivations of health answerers for sharing information,

- knowledge, and experiences in online environments. *Journal of the American Society for Information Science and Technology*, 63(3), 543–557. doi:10.1002/asi.21676
- Oliver, P., Marwell, G., & Teixeira, R. (1985). A theory of the critical mass. I. Interdependence, group heterogeneity, and the production of collective action. *American Journal of Sociology*, 91(3), 522–556. Retrieved August 2, 2015, from <http://www.jstor.org/stable/2780201>
- Oreg, S., & Nov, O. (2008). Exploring motivations for contributing to open source initiatives: The roles of contribution context and personal values. *Computers in Human Behavior*, 24(5), 2055–2073. doi:10.1016/j.chb.2007.09.007
- Palloff, R. M., & Pratt, K. (2010). *Collaborating Online: Learning Together in Community*. John Wiley & Sons. Retrieved June 18, 2015, from <http://www.google.co.uk/books?hl=en&lr=&id=jjEzu9cevAMC&pgis=1>
- Palloff, R., & Pratt, K. (2007). *Building Online Learning Communities: Effective Strategies for the Virtual Classroom*. John Wiley & Sons. Retrieved June 18, 2015, from https://www.google.com/books?hl=en&lr=&id=VSnl3mla_x8C&oi=fnd&pg=PR9&dq=Building+online+learning+communities:+Effective+strategies+for+the+virtual+classroom.&ots=NzSB6rP510&sig=3gdE3xyB_1MnHByNhbcCIRsRaIM
- Parry, S. (2009). Stem cell scientists' discursive strategies for cognitive authority. *Science as Culture*, 18(1), 89–114. doi:10.1080/09505430802603837
- Patel, M., Capps, D. K., Baram-Tsabari, A., & Crawford, B. A. (2011). Promoting students' interest in science: Inquiry-based instruction and an authentic investigation. In C. Bruguère, A. Tiberghien, & C. Pierre (Eds.), *Ebook Proceedings Of The Esera 2011 Conference: Science learning and Citizenship*. Lyon, France: Science Education Research Association (ESERA).
- Patton, M. Q. (1990). *Qualitative Evaluation and Research Methods (2nd ed.)*. Thousand Oaks, CA: Sage Publications, Inc. Retrieved June 21, 2015, from <http://psycnet.apa.org/psycinfo/1990-97369-000>
- Pham, M., Derntl, M., Cao, Y., & Klamma, R. (2012). Learning analytics for learning blogospheres. In E. Popescu, Q. Li, R. Klamma, H. Leung, & M. Specht (Eds.), *Advances in Web-Based Learning, Proceedings of 11th International Conference – ICWL2012* (pp. 258–267). doi:10.1007/978-3-642-33642-3_28
- Philip Gibbs. (1997). *Why is the Sky Blue?* Original Usenet Physics FAQ. Retrieved October 3, 2015, from http://math.ucr.edu/home/baez/physics/General/BlueSky/blue_sky.html
- Phillips, T., Bonney, R., & Shirk, J. (2012). What is our impact? Toward a unified framework for evaluating impacts of citizen science. In J. Dickinson & R. Bonney (Eds.), *Citizen Science: Public Participation in Environmental Research* (pp. 82–95). Cornell University Press. Retrieved June 2, 2015, from https://scholar.google.gr/scholar?q=What+is+our+impact%3F+Toward+a+unified+framewor+k+for+evaluating+impacts+of+citizen+science.+&btnG=&hl=en&as_sdt=0%2C5#0
- Polin, L. (2010). Graduate professional education from a community of practice perspective: the role of social and technical networking. In C. Blackmore (Ed.), *Social Learning Systems and Communities of Practice* (pp. 163–178). London: Springer. doi: 10.1007/978-1-84996-133-2_10

- Ponciano, L., & Brasileiro, F. (2015). Finding Volunteers' Engagement Profiles in Human Computation for Citizen Science Projects. *Human Computation*, 1(2), 245-264. doi:10.15346/hc.v1i2.12
- Postmes, T., & Spears, R. (2002). Behavior Online: Does Anonymous Computer Communication Reduce Gender Inequality? *Personality and Social Psychology Bulletin*, 28(8), 1073–1083. doi:10.1177/01461672022811006
- Postmes, T., & Spears, R. (2005). Individuality and social influence in groups: inductive and deductive routes to group identity. *Journal of Personality and Social Psychology*, 89(5), 747–763. doi:10.1037/0022-3514.89.5.747
- Postmes, T., Spears, R., & Lea, M. (2002). Intergroup differentiation in computer-mediated communication: Effects of depersonalization. *Group Dynamics: Theory, Research, and Practice*, 6(1), 3–15. doi:10.1037/1089-2699.6.1.3
- Powell, J. H., Nash, G. V., & Bell, P. D. (2013, June 6). GeoExposures: documenting temporary geological exposures in Great Britain through a citizen-science web site. *Proceedings of the Geologists' Association*, 124(4), 638–647. Elsevier. doi:10.1016/j.pgeola.2012.04.004
- Preece, J. (2000). *Online Communities: Designing Usability and Supporting Socialbility*. New York, NY: John Wiley & Sons, Inc. Retrieved August 1, 2015, from <http://dl.acm.org/citation.cfm?id=517688>
- Preece, J. (2001). Sociability and usability in online communities: Determining and measuring success. *Behaviour & Information Technology*, 20(5), 347-356. doi:10.1080/01449290110084683
- Preece, J., Nonnecke, B., & Andrews, D. (2004). The top five reasons for lurking: improving community experiences for everyone. *Computers in Human Behavior*, 20(2), 201–223. doi:10.1016/j.chb.2003.10.015
- Preece, J., & Shneiderman, B. (2009). The Reader-to-Leader Framework: Motivating Technology-Mediated Social Participation. *AIS Transactions on Human-Computer Interaction*, 1(1), 13–32. Retrieved July 5, 2015, from <http://aisel.aisnet.org/thci/vol1/iss1/5>
- Raddick, M. J., Bracey, G., Gay, P. L., Lintott, C. J., Murray, P., Schawinski, K., ... Vandenberg, J. (2010). Galaxy Zoo: Exploring the Motivations of Citizen Science Volunteers. *Astronomy Education Review*, 9(1), 15 pages. doi:10.3847/AER2009036
- Raddick, M. J., Bracey, G., Gay, P. P. L., Lintott, C. J., Cardamone, C., Murray, P., ... Vandenberg, J. (2013). Galaxy Zoo: Motivations of Citizen Scientists. *Astronomy Education Review*, 12(1), 27 pages. Retrieved from <http://scitation.aip.org/content/aas/journal/aer/12/1/10.3847/AER2011021?crawler=true&mimetype=application/pdf>
- Reeves, T. (2000). Enhancing the worth of instructional technology research through “design experiments” and other development research strategies. *International Perspectives on Instructional Technology Research for the 21st Century*, 27, 1–15. Retrieved June 30, 2015, from <http://www.teknologipendidikan.net/wp-content/uploads/2009/07/Enhancing-the-Worth-of-Instructional-Technology-Research-through3.pdf>

- Ren, Y., & Kraut, R. (2012). Encouraging commitment in online communities. In R. E. Kraut, & P. Resnick (Eds.), *Building Successful Online Communities: Evidence-based Social Design* (pp. 179–230). MIT Press. Retrieved July 25, 2015, from <https://books.google.com/books?hl=en&lr=&id=llvBMYVxWJYC&pgis=1>
- Ren, Y., & Kraut, R. E. (2013). Agent-Based Modeling to Inform Online Community Design: Impact of Topical Breadth, Message Volume, and Discussion Moderation on Member Commitment and Contribution. *Human–Computer Interaction*, 29(4), 351–389. doi:10.1080/07370024.2013.828565
- Resnick, P., & Konstan, J. (2012). Starting New Online Communities. In R. E. Kraut, & P. Resnick (Eds.), *Building Successful Online Communities: Evidence-based Social Design* (pp. 179–230). MIT Press. Retrieved July 25, 2015, from <https://books.google.com/books?hl=en&lr=&id=llvBMYVxWJYC&pgis=1>
- Revere, L., & Kovach, J. (2011). Online technologies for engaged learning. *Quarterly Review of Distance Education*, 12(2), 113–124. Retrieved July 31, 2015, from <http://search.proquest.com/openview/ee56bfc90cac37ad96a4f6be61918f02/1?pq-origsite=gscholar>
- Richardson, J., & Swan, K. (2003). Examining social presence in online courses in relation to students' perceived learning and satisfaction. *Journal of Asynchronous Learning Networks*, 7(1), 68–88. Retrieved July 5, 2015, from <https://www.ideals.illinois.edu/handle/2142/18713>
- Richardson, J. T. (1994). The analysis of 2 x 1 and 2 x 2 contingency tables: an historical review. *Statistical Methods in Medical Research*, 3(2), 107–133. doi:10.1177/096228029400300202
- Ridings, C., & Gefen, D. (2004). Virtual community attraction: Why people hang out online. *Journal of Computer-Mediated Communication*, 10(1). doi:10.1111/j.1083-6101.2004.tb00229.x
- Ridings, C., Gefen, D., & Arinze, B. (2006). Psychological barriers: Lurker and poster motivation and behavior in online communities. *Communications of the Association of Information Systems*, 18, article no. 16. Retrieved June 29, 2015, from <http://aisel.aisnet.org/cgi/viewcontent.cgi?article=3087&context=cais>
- Robson, C. (2012). *Using Mobile Technology and Social Networking to Crowdsource Citizen Science* (Doctoral Dissertation, UC Berkeley, USA). Retrieved July 31, 2015, from <http://escholarship.org/uc/item/7pb628kb#page-72>
- Rodgers, S., & Chen, Q. (2005). Internet community group participation: Psychosocial benefits for women with breast cancer. *Journal of Computer-Mediated Communication*, 10(4). doi:10.1111/j.1083-6101.2005.tb00268.x
- Romeo, F., & Blaser, L. (2011). Bringing citizen scientists and historians together. In J. Trant & D. Bearman (Eds.), *Proceedings of Museums and the Web*. Toronto: Archives and Museums Informatics. Retrieved July 23, 2015, from http://www.museumsandtheweb.com/mw2011/papers/bringing_citizen_scientists_and_historians_tog
- Root, T. (1988). *Atlas of Wintering North American Birds: an Analysis of Christmas Bird Count Data* The University of Chicago Press. Retrieved June 17, 2015, from https://books.google.co.uk/books/about/Atlas_of_Wintering_North_American_Birds.html?i

- Rossmann, G. B., & Wilson, B. L. (1985). Numbers and Words: Combining Quantitative and Qualitative Methods in a Single Large-Scale Evaluation Study. *Evaluation Review*, 9(5), 627–643. doi:10.1177/0193841X8500900505
- Roth, W. (2012). *Authentic school science: Knowing and Learning in Open-inquiry Science Laboratories*. Springer. Retrieved December 2, 2015, from <https://books.google.co.uk/books?hl=en&lr=&id=wulhBAAAQBAJ&oi=fnd&pg=PT7&dq=Authentic+school+science.+&ots=gWSOLFubMf&sig=RQ91NOPRZHRXaGWptrY7XfJ2Y08>
- Rotman, D., Preece, J., Hammock, J., Procita, K., Hansen, D., Parr, C., ... Jacobs, D. (2012). Dynamic changes in motivation in collaborative citizen-science projects. In *Proceedings of the ACM 2012 Conference on Computer Supported Cooperative Work* (pp. 217–226). New York, USA: ACM. doi:10.1145/2145204.2145238
- Rousseeuw, P. (1987). Silhouettes: a graphical aid to the interpretation and validation of cluster analysis. *Journal of Computational and Applied Mathematics*, 20, 53–65. doi:10.1016/0377-0427(87)90125-7.
- Salmon, G. (2012). *E-Moderating: The Key to Online Teaching and Learning*. Routledge. Retrieved September 13, 2015, from <https://books.google.com/books?hl=en&lr=&id=aXGsAgAAQBAJ&pgis=1>
- Sapsford, R. (2006). *Survey Research* (Vol. 15). SAGE Publications. Retrieved July 1, 2015, from <https://books.google.com/books?hl=en&lr=&id=NOAGd7Hx9F4C&pgis=1>
- Sassenberg, K. (2002). Common bond and common identity groups on the Internet: Attachment and normative behavior in on-topic and off-topic chats. *Group Dynamics: Theory, Research, and Practice*, 6(1), 27–37. doi: 10.1037/1089-2699.6.1.27
- Sauro, J. (2011). *A Practical Guide to the System Usability Scale: Background, Benchmarks & Best Practices*. Denver, CO: Measuring Usability LLC.
- Scanlon, E. (2012). Open educational resources in support of science learning: tools for inquiry and observation. *Distance Education*, 33(2), 221–236. doi:10.1080/01587919.2012.692053
- Scanlon, E., Anastopoulou, S., & Kerawalla, L. (2012). Inquiry learning reconsidered; contexts, representations and challenges. In K. Littleton, E. Scanlon, & M. Sharples (Eds.), *Orchestrating Inquiry Learning* (pp. 7–30). Abingdon, England: Routledge. Retrieved June 3, 2015, from <http://oro.open.ac.uk/31359/>
- Scanlon, E., Anastopoulou, S., Kerawalla, L., & Mulholland, P. (2011). How technology resources can be used to represent personal inquiry and support students' understanding of it across contexts. *Journal of Computer Assisted Learning*, 27(6), 516–529. doi:10.1111/j.1365-2729.2011.00414.x
- Scanlon, E., Woods, W., & Clow, D. (2014). Informal Participation in Science in the UK : Identification , Location and Mobility with iSpot. *Journal of Educational Technology and Society*, 17(2), 58–71. Retrieved July 7, 2015, from http://www.jstor.org/stable/jeductechsoci.17.2.58?seq=1#page_scan_tab_contents
- Scharwitz, D., Lin, X., Brophy, S., & Bransford, J. (1999). Toward the development of flexibility

- adaptive instructional design. *Instructional-Design Theories and Models: A New Paradigm of Instructional Theory*, 2, 183–214. Retrieved June 10, 2015, from https://www.researchgate.net/publication/243681009_Toward_the_development_of_flexibly_adaptive_instructional_designs
- Schwartz, R. S., Lederman, N. G., & Crawford, B. A. (2004). Developing views of nature of science in an authentic context: An explicit approach to bridging the gap between nature of science and scientific inquiry. *Science Education*, 88(4), 610–645. doi:10.1002/sce.10128
- Sharples, M., & Anastopoulou, S. (2012). Designing orchestration for inquiry learning. In K. Littleton, E. Scanlon, & M. Sharples (Eds.), *Orchestrating Inquiry Learning* (pp. 69–85). Abingdon, England: Routledge. Retrieved June 30, 2015, from <http://www.cross-field.ch/wp-content/uploads/2013/01/SharplesAnastopoulou.docx>
- Sharples, M., McAndrew, P., Weller, M., Ferguson, R., FitzGerald, E., Hirst, T., & Gaved, M. (2013). *Innovating Pedagogy 2013: Exploring New Forms of Teaching, Learning and Assessment, to Guide Educators and Policy Makers. Innovation Report 2*. The Open University. Retrieved June 3, 2015, from http://www.open.ac.uk/iet/main/sites/www.open.ac.uk.iet.main/files/files/ecms/web-content/Innovating_Pedagogy_report_2013.pdf
- Sharples, M., Scanlon, E., Ainsworth, S., Anastopoulou, S., Collins, T., Crook, C., ... O'Malley, C. (2014). Personal inquiry: Orchestrating science investigations within and beyond the classroom. *Journal of the Learning Sciences*, 24(2), 308–341. doi:10.1080/10508406.2014.944642
- Shea, P., & Bidjerano, T. (2009). Community of inquiry as a theoretical framework to foster “epistemic engagement” and “cognitive presence” in online education. *Computers & Education*, 52(3), 543–553. doi:10.1016/j.compedu.2008.10.007
- Shenton, A. (2004). Strategies for ensuring trustworthiness in qualitative research projects. *Education for Information*, 22(2), 63–75. Retrieved June 23, 2015, from <https://xa.yimg.com/kq/groups/73868647/750861395/name/Trustworthypaper.pdf>
- Shimoda, T., White, B., & Frederiksen, J. (2002). Student goal orientation in learning inquiry skills with modifiable software advisors. *Science Education*, 86(2), 244–263. doi:10.1002/sce.10003
- Shirk, J. L., Ballard, H. L., Wilderman, C. C., Phillips, T., Wiggins, A., Jordan, R., ... Bonney, R. (2012). Public participation in scientific research: a framework for deliberate design. *Ecology and Society*, 17(2), article no. 29. doi:10.5751/ES-04705-170229
- Shoham, M. (2013). Writing on the Wall: An Online “Community” of YouTube Patrons as Communication Network or Cyber-Graffiti? Proceedings of 46th Hawaii International Conference on System Sciences – HICSS (pp. 3951–3960). IEEE. doi: 10.1109/HICSS.2013.615
- Silverman, D. (2006). *Interpreting Qualitative Data: Methods for Analyzing Talk, Text and Interaction*. SAGE Publications. Retrieved June 20, 2015, from <https://books.google.com/books?hl=en&lr=&id=uooz4p82sDgC&pgis=1>
- Slater, M., Howell, J., Steed, A., Pertaub, D.-P., & Garau, M. (2000). Acting in virtual reality. In *Proceedings of the Third International Conference on Collaborative Virtual Environments* –

CVE '00 (pp. 103–110). New York, USA: ACM Press. doi:10.1145/351006.351020

- Smith, R. W. (1975). *Strategies of Social Research: the Methodological Imagination*. London: Prentice- Hall. Retrieved July 10, 2015, from <http://search.proquest.com/openview/3028e4c8cc9e84658430e032c97cb1a8/1?pq-origsite=gscholar>
- Stewart, K., & Williams, M. (2005). Researching online populations: the use of online focus groups for social research. *Qualitative Research*, 5(4), 395–416. doi:10.1177/1468794105056916
- Stodden, V. C. (2010). Open science: Policy implications for the evolving phenomenon of user-led scientific innovation. *Journal of Science Communication*, 9(1), 1–8. Retrieved July 24, 2015, from <http://academiccommons.columbia.edu/catalog/ac:140127>
- Struyf, A., Hubert, M., & Rousseeuw, P. (1996). Clustering in an Object-Oriented Environment. *Journal of Statistical Software*, 1(4), 1–30. doi:10.18637/jss.v001.i04
- Stuckey, B., & Smith, J. (2004). Building sustainable communities of practice. In P. Hildreth & C. Kimble (Eds.), *Knowledge Networks: Innovation through Communities of Practice* (pp. 150–162). Retrieved July 9, 2015, from <https://www.google.com/books?hl=en&lr=&id=BTZ9zavaRLAC&oi=fnd&pg=PA150&dq=Building+sustainable+communities+of+practice&ots=18pI5Dfdhl&sig=32uRybJx0b0Yh5vPA6d-cM2UOcM>
- Sultan, F., Farley, J., & Lehmann, D. (1990). A meta-analysis of applications of diffusion models. *Journal of Marketing Research*, 27(1), 70–77. doi:10.2307/3172552
- Sun, N., Rau, P. P.-L., & Ma, L. (2014). Understanding lurkers in online communities: A literature review. *Computers in Human Behavior*, 38, 110–117. doi:10.1016/j.chb.2014.05.022
- Sundaram, D., Mitra, K., & Webster, C. (1998). Word-of-mouth communications: A motivational analysis. *Advances in Consumer Research*, 25, 527–531. Retrieved November 1, 2015, from <http://www.acrwebsite.org/search/view-conference-proceedings.aspx?Id=8208>
- Sundberg, M., & Moncada, G. (1994). Creating effective investigative laboratories for undergraduates. *BioScience*, 44(10), 698–704. doi:10.2307/1312513
- Suriowecki, J. (2005). The Wisdom of Crowds: Why the Many Are Smarter Than the Few. *Business Economics*, 41(4), 63–65. Retrieved September 23, 2015, from <http://go.galegroup.com/ps/anonymouse?id=GALE|A157356956&sid=googleScholar&v=2.1&it=r&linkaccess=fulltext&issn=0007666X&p=AONE&sw=w&authCount=1&isAnonymousEntry=true>
- Swan, K., & Shih, L. (2005). On the nature and development of social presence in online course discussions. *Journal of Asynchronous Learning Networks*, 9(3), 115–136. Retrieved August 4, 2015, from <http://anitacrawley.net/Articles/Swan and Shih2005.pdf>
- Sweeney, J., Soutar, G., & Mazzarol, T. (2014). Factors enhancing word-of-mouth influence: positive and negative service-related messages. *European Journal of Marketing*, 48(1/2), 336–359. doi: 10.1108/EJM-06-2012-0336
- Symonds, J. E., & Gorard, S. (2010). Death of mixed methods? Or the rebirth of research as a craft. *Evaluation & Research in Education*, 23(2), 121–136. doi:10.1080/09500790.2010.483514

- Tashakkori, A., & Teddlie, C. (1998). *Mixed methodology: Combining Qualitative and Quantitative Approaches*. Thousand Oaks, Calif: Sage Publications. Retrieved August 29, 2015, from <http://www.erudit.org/revue/RI/2000/v55/n3/051336ar.pdf>
- Teddlie, C., & Tashakkori, A. (2009). *Foundations of Mixed Methods Research: Integrating Quantitative and Qualitative Approaches in the Social and Behavioral Sciences*. Sage Publications, Inc. Retrieved June 30, 2015, from <https://books.google.co.uk/books?hl=en&lr=&id=XvMAYYvS1rEC&oi=fnd&pg=PT1&dq=Foundations+of+Mixed+Methods+Research:+Integrating+Quantitative+and+Qualitative+Approaches+in+the+Social+and+Behavioral&ots=hNwoMOZkMs&sig=8a36g2WIHqPyS5QFmHiplYLI0XM>
- Thomas, G. (2013). *How to Do Your Research Project: A Guide for Students in Education and Applied Social Sciences*. SAGE Publications. Retrieved August 7, 2015, from <https://books.google.com/books?hl=en&lr=&id=8ruP-gEtDwG&pgis=1>
- Trusov, M., Bucklin, R., & Pauwels, K. (2009). Effects of word-of-mouth versus traditional marketing: Findings from an internet social networking site. *Journal of Marketing*, 73(5), 90–102. doi:10.1509/jmkg.73.5.90
- Velasquez, A., Wash, R., Lampe, C., & Bjornrud, T. (2014). Latent users in an online user-generated content community. *Computer Supported Cooperative Work (CSCW)*, 23(1), 21–50. doi:10.1007/s10606-013-9188-4
- Villasclaras-Fernandez, E., Sharples, M., Kelley, S., & Scanlon, E. (2013). Supporting Citizen Inquiry: An Investigation of Moon Rock. In D. Hernández-Leo, T. Ley, R. Klamma, & A. Harrer (Eds.), *Scaling up Learning for Sustained Impact, Proceedings of 8th European Conference, on Technology Enhanced Learning – EC-TEL 2013* (pp. 383–395). Paphos, Cyprus: Springer Berlin Heidelberg. doi:10.1007/978-3-642-40814-4
- Vreede, T. De, Nguyen, C., Vreede, G. De, Boughzala, I., Oh, O., & Reiter-Palmon, R. (2013). A Theoretical Model of User Engagement in Crowdsourcing. In P. Antunes, M. A. Gerosa, A. Sylvester, J. Vassileva, & G. de Vreede (Eds.), *Collaboration and Technology, Proceedings of 19th International Conference – CRIWG 2013* (pp. 94–109). Wellington, New Zealand: Springer Berlin Heidelberg. doi:10.1007/978-3-642-41347-6_8
- Vygotsky, L. S. (1980). *Mind in Society: The Development of Higher Psychological Processes*. Harvard University Press.
- Wald, D. M., Longo, J., & Dobell, A. R. (2015). Design Principles for Engaging and Retaining Virtual Citizen Scientists. *Conservation Biology*, n/a–n/a. doi:10.1111/cobi.12627
- Walther, J., Slovacek, C., & Tidwell, L. (2001). Is a picture worth a thousand words? Photographic images in long-term and short-term computer-mediated communication. *Communication Research*, 28(1), 105–134. doi:10.1177/009365001028001004
- Wang, F., & Hannafin, M. (2005). Design-based research and technology-enhanced learning environments. *Educational Technology Research and Development*, 53(4), 5–23. doi:10.1007/BF02504682
- Wasko, M., & Faraj, S. (2000). “It is what one does”: why people participate and help others in electronic communities of practice. *The Journal of Strategic Information Systems*, 9(2-3),

- Wasko, M., & Faraj, S. (2005). Why should I share? Examining social capital and knowledge contribution in electronic networks of practice. *MIS Quarterly*, 29(1), 35–57. Retrieved August 9, 2015, from <http://www.jstor.org/stable/25148667>
- Wasserman, S., & Faust, K. (1994). *Social Network Analysis: Methods and Applications* (Vol. 25). Cambridge University Press. Retrieved June 19, 2015, from <https://books.google.com/books?hl=en&lr=&id=CAm2DplqRUIC&pgis=1>
- Weber, S. (2007). *Das Google-Copy-Paste-Syndrom. Wie Netzplagiate Ausbildung Und Wissen Gefährden*. Hannover: Heise. Retrieved July 21, 2015, from http://www.heise.de/tp/buch/buch_25.html
- Wenger, E. (1988). *Communities of Practice: Learning, Meaning and Identity*. Cambridge University Press. doi:10.2277/0521663636
- Wenger, E. (2001). *Supporting communities of practice: a survey of community-oriented technologies*. Retrieved July 2, 2015, from http://go.webassistant.com/4u/upload/users/u1000471/cop_technology_2001.pdf
- Wenger, E. (2010). Communities of practice and social learning systems: the career of a concept. In C. Blackmore (Ed.), *Social Learning Systems and Communities of Practice* (pp. 179–198). Springer Verlag and the Open University. doi:10.1007/978-1-84996-133-2_11
- Wenger, E., McDermott, R. A., & Snyder, W. (2002). *Cultivating Communities of Practice: A Guide to Managing Knowledge*. Harvard Business School Press. Retrieved June 20, 2015, from <https://books.google.com/books?hl=en&lr=&id=m1xZuNq9RygC&pgis=1>
- Westland, C. J. (2010). Critical mass and willingness to pay for social networks. *Electronic Commerce Research and Applications*, 9(1), 6–19. doi:10.1016/j.elerap.2009.05.003
- White, B., & Frederiksen, J. (1998). Inquiry, modeling, and metacognition: Making science accessible to all students. *Cognition and Instruction*, 16(1), 3–118. doi:10.1207/s1532690xc1601_2
- Wiggins, A., & Crowston, K. (2010). Developing a conceptual model of virtual organisations for citizen science. *International Journal of Organisational Design and Engineering*, 1(1-2), 148–162. doi:10.1504/IJODE.2010.035191
- Wiggins, A., & Crowston, K. (2011). From conservation to crowdsourcing: A typology of citizen science. Proceedings of the 44th Hawaii International Conference on System Sciences – HICSS (pp. 1–10). Kuai, HI: IEEE. doi:10.1109/HICSS.2011.207
- Wiggins, A., & Crowston, K. (2012). Goals and tasks: Two typologies of citizen science projects. Proceedings of the 45th Hawaii International Conference on System Sciences – HICSS (pp. 3426–3435). Maui, HI: IEEE. doi:10.1109/HICSS.2012.295
- Wilderman, C. (2004). *Portrait of a Watershed: Shermans Creek* (A Technical Status Report). Retrieved June 25, 2015, from <http://www.shermanskreek.org/ShermansCreekPortrait.pdf>
- Wilkinson, S. (1998). Focus groups in feminist research. *Women's Studies International Forum*, 21(1), 111–125. doi:10.1016/S0277-5395(97)00080-0

- Woodgate, D., Stanton Fraser, D., Paxton, M., Crellin, D., Woolard, A., & Dillon, T. (2008). Bringing school science to life: personalization, contextualization and reflection of self-collected data. *Proceedings of Fifth IEEE International Conference on Wireless, Mobile and Ubiquitous Technologies in Education – WMUTE 2008* (pp. 100–104). Beijing: IEEE. doi:10.1109/WMUTE.2008.35
- Woods, W., & Scanlon, E. (2012). iSpot Mobile - A Natural History Participatory Science Application. In M. Specht, M. Sharples & J. Multisilta (Eds.), *Proceedings of 11th World Conference on Mobile and Contextual Learning - mLearn 2012* (pp. 25–33). Helsinki, Finland: CEUR. Retrieved July 9, 2015, from http://ceur-ws.org/Vol-955/papers/paper_9.pdf
- Worchel, S., & Rothgerber, H. (1998). Social identity and individual productivity within groups. *British Journal of Social Psychology*, 37(4), 389–413. doi:10.1111/j.2044-8309.1998.tb01181.x
- Yee, N., Bailenson, J., & Rickertsen, K. (2007). A meta-analysis of the impact of the inclusion and realism of human-like faces on user experiences in interfaces. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 1–10). doi:10.1145/1240624.1240626
- Young, C. (2013). Community management that works: how to build and sustain a thriving online health community. *Journal of Medical Internet Research*, 15(6), e119. doi:10.2196/jmir.2501
- Yuki, M., Maddux, W. W., Brewer, M. B., & Takemura, K. (2005). Cross-cultural differences in relationship- and group-based trust. *Personality & Social Psychology Bulletin*, 31(1), 48–62. doi:10.1177/0146167204271305
- Zaccaro, S., & Dobbins, G. (1989). Contrasting group and organizational commitment: Evidence for differences among multilevel attachments. *Journal of Organizational Behavior*, 10(3), 267–273. doi:10.1002/job.4030100306
- Zajonc, R. (1968). Attitudinal effects of mere exposure. *Journal of Personality and Social Psychology*, 9(2), 1–28. doi:10.1037/h0025848

Appendices

Appendix A: Design Study 1 – Geology vocabulary

- A)** Abrade, Acid, Aeration, Aftershock, Alloy, Alluvial, Alter, Alteration, Anodize, Aquifer, Assessment, Avalanche
- B)** Back reef, Bacteria, Basin, Batholith, Bedrock, Burning, Butte
- C)** Calcium, Calcium carbonate, Carbon dioxide, Carbon-14 dating, Carbonic acid, Carve, Cataclysm, Cavern, Cavities, Change, Chemical reaction, Chimney, Cinder cone, Cirque, Classified, Climate changes, Clod, Collision, Compaction, Composite, Composition, Compression, Cone, Configuration, Continent, Continental, Coral, Crag, Creep, Crevasse, Crust, Crystals, Cycle
- D)** Dampness, Decay, Decomposition, Delta, Dendrite, Denude, Deposits, Depth, Detritus, Dike, Dilute, Disaster, Discovery, Dissolution, Dissolve, Distance, Dome, Drainage
- E)** Earthquake, Elements, Elevation, Eluvium, Environment, Eolian, Epicenter, Epoch, Erosion, Esker, Evaporation, Examination, Exploration, Explosion, Extinction, Extrude
- F)** Facet, Fault, Feldspar, Fissure, Flowstone, Fluvial, Foliation, Force, Formations, Fossil, Fracture, Fuel
- G)** Geode, Geodesic, Geologic, Geologist, Geothermal, Geyser, Glacial, Glacier, Gravity, Grotto, Groundwater, Guyot, Gypsum
- H)** Hade, Honeycombed, Horizon, Humidity, Humus, Hyaline, Hydrocarbon, Hydrogen sulfide, Hydrologic
- I)** Ice age, Icecap, Igneous, Illumination, Imminent, Impact, Impassable, Inanimate, Inquiry, Instruments, Integrity, Intrusive
- J)** Joint, Jurassic, Jutting
- K)** Karst, Keen, Kettle lake
- L)** Landmark, Landscape, Landslide, Launch, Lava, Layer, Leach, Lethal, Lignite, Limestone, Lithosphere, Lodestone, Loess, Luminous, Luster
- M)** Magma, Mantle, Massif, Matter, Meander, Measurements, Mesa, Metamorphosis, Microbe, Migration, Millennia, Minerals, Moisture, Molten, Monograph, Monolith, Mosaic, Movement
- N)** Nubbin, Numerous
- O)** Oasis, Objects, Obsidian, Official, Oolites (cave pearls), Organic, Outcropping, Outwash plain, Oxygen
- P)** Paleoclimates, Paleontologist, Passageways, Percolate, Permafrost, Permian, Petrified, Petrify, Petrographer, Physical, Plate, Plateau, Playa, Porous, Precipitation, Prediction, Pressure, Pristine, Probe, Prospecting
- Q)** Quarry, Quartz, Quest, Questions, Quit
- R)** Ratios, Reef, Residual, Richter scale, Rift, Rill, Rimrock, Rivers, Rocks, Rockslide, Rubble, Runoff
- S)** Salt, Sandstone, Saturation, Schist, Scientific, Scree, Sculpt, Sedimentary, Seepage, Seismic, Shale, Shard, Shelf, Shelf stone, Shift, Slag, Slope, Slurry, Soil, Speleologist, Spew, Stalactite, Stalagmites, Stone, Stratification, Subterranean, Sulfuric acid
- T)** Talus, Tectonic, Thermals, Thrust, Tilt, Topography, Trail head, Triassic, Tundra
- U)** Underground, Unearth, Unique, Unity, Universal, Upheaval, Upstream
- V)** Vapor, Vein, Vent, Ventifact, Vitreous, Volcano, Volume
- W)** Waterfalls, Weathering, Wonder, Worldwide
- X)**
- Y)**
- Z)** Zealous, Zero-impact, Zest, Zigzag, Zone

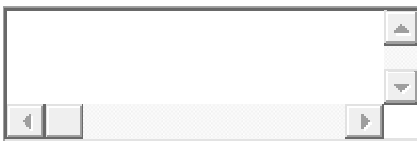
Appendix B: Design Study 1 – Interviews and online focus group

1. *For experts only:* What recommendations would you give for other people that take part to make the most of the experience? What is your advice for somebody who is starting an inquiry?
2. What did you like the most in this project?
 - a. Was there any tool you have been using frequently?
 - b. Which stage of the inquiry process was the easiest or pleasant for you?
3. What did you like the least in this project?
4. What would you like to change?
 - a. Could you use the platform without any instructions?
 - b. How useful did you find the tutorials, instructions and video.
 - c. Was there anything that made it difficult for you to complete your inquiry?
 - d. Do you think the tools are satisfactory for the purposes of the inquiry?
 - e. Chat: Did you use the chat? Did you find the chat useful? How many people have you chatted with? What types of chat did you have? (task focused, asking a question, social interaction)
 - f. Which aspects of the tool have you found more useful? (Inquiry, forum, Publishing, chat). Why?
5. Did you learn something from your experience?
 - a. If yes, what was that?
 - b. If no, would you participate again in such a study even if you haven't learnt anything new? Why?

1. Describe your experience of geology:

- ☐ Expert
- ☐ Intermediate
- ☐ Beginner/amateur

Could you please expand on your response?



2. Did you receive any help during your inquiring process?

- ☐ Yes ☐ No

If "yes", you received help for:

- ☐ The stages of the inquiry process
- ☐ The rock identification
- ☐ The use of geology techniques
- ☐ Other (*please specify*):



3. At which point of the inquiry did you need help from the nQuire community?

(*select all that apply*)

- ☐ Decide my theme
- ☐ Form my question

- ☐ Plan my method
- ☐ Collect my data
- ☐ Analyse my data
- ☐ Decide and share my conclusions
- ☐ N/A

4. From whom did you receive help?

(select all that apply)

- ☐ People in the nQuire community
- ☐ A geology expert
- ☐ None
- ☐ Other *(please specify)*:

a. If you received any help from the nQuire community, was it useful?

- ☐ Yes
- ☐ No
- ☐ N/A

b. If you received any help, could you please describe how you made use of that help in your inquiries?

5. Did you give any help to other participants? If yes, in which way?

A large rectangular text input area with a light gray border. On the right side, there are three small square buttons stacked vertically. On the bottom left, there are two small square buttons side-by-side. On the bottom right, there is a small square button.

6. Which way do you prefer to communicate/collaborate with other users?

(select all that apply)

☐ Question to expert

☐ Other Forum Topics

☐ Online Chat

☐ Other *(please specify)*:

A single-line text input field with a light gray border.

Please explain why.

A large rectangular text input area with a light gray border. On the right side, there are three small square buttons stacked vertically. On the bottom left, there are two small square buttons side-by-side. On the bottom right, there is a small square button.

7. How difficult was it to form your own question?

☐ I didn't form my own question

☐ Difficult

☐ I needed some guidance to revise it

☐ Easy

8. Which tools did you use during your inquiry?

(select all that apply)

☐ Camera ☐ Notebook ☐ Identification Key ☐ Maps ☐ Microscope ☐ GPS

☐ Hardness test toolkit

☐ Other *(please specify)*:

Do you have any suggestion for the improvement of the above tools?

9. Is there any other tool you would like to have available during your inquiry?

10. Have you learnt anything new or interesting through your participation in this study?

11. What motivated you to participate in this study?

Apart from geology, are there any other topics you would be interested in pursuing an inquiry on?

"Inquiring Rock Hunters": Questionnaire 2

Below are number of questions about the usability of nQuire tool. Please read each one and select to what extent you agree or disagree with each statement. There are no right or wrong answers.

1. System Usability Scale

	System Usability Scale				
	Strongly Disagree	Disagree	Neither agree nor disagree	Agree	Strongly Agree
a. I think that I would like to use nQuire frequently	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
b. I found nQuire unnecessarily complex	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
c. I thought nQuire was easy to use	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
d. I think that I would need the support of a technical person to be able to use nQuire	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
e. I found the various functions in nQuire were well integrated	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
f. I thought there was too much inconsistency in nQuire	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
g. I would imagine that most people would learn to use nQuire very quickly	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
h. I found the nQuire very cumbersome to use	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
i. I felt very confident using nQuire	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
j. I needed to learn a lot of things before I could get going with nQuire	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Case 1: Interview with an active member

1. What did you like the most in this project?
2. What did you like the least in this project?
3. Has Weather-it community met your initial expectations?
4. Did you collaborate with other members in a mission? If not, what prevented you?
5. How was the experience?
6. Did you create a mission? If not, why?
7. Are you still active on nQuire-it?
8. What are you involved with? Are there any plans over the next days?
9. Are you planning to stay on the platform for Weather-it or other missions?
10. If not, what will be the reasons for stopping?
11. Is there anything you would you like to change on nQuire-it?

Case 2: Interview with a drop out after being active

1. What did you like the most in this project?
2. What did you like the least in this project?
3. Has Weather-it community met your initial expectations?
4. Did you collaborate with other members in a mission? If not, what prevented you?
5. How was the experience?
6. Did you create a mission? If not, why?
7. Are you still active on nQuire-it?
8. What will be the reasons for stopping?
9. What could Weather-it have done to make you not leave?
10. What would you like to change on nQuire-it to become active again?

Case 3: Interview with a lurker

1. What did you like the most in this project?
2. What did you like the least in this project?
3. Has Weather-it community met your initial expectations?
4. Have you participated in any mission or forum discussion?
5. What prevented you?
6. Are you still active on nQuire-it?
7. Is there anything you would you like to change on nQuire-it to become more active?
8. Are you planning to stay on the platform for Weather-it or other missions?

Case 4: Interview with experts

1. What did you like the most in this project?
2. What did you like the least in this project?
3. Has Weather-it community met your initial expectations?
4. Did you collaborate with other members in a mission?
5. How was the experience?
6. Did you create a mission?
“yes”: how easy/difficult was it to create and maintain it?
“no”: why?
7. Have you found Weather-it effective in engaging people with weather investigation?
8. Is there anything you would you like to change to make it more effective?
9. Are you planning to stay on the platform for Weather-it or other missions?

Case 5: Interview with members who participated in both projects

1. What did you like the most in this project?
2. What did you like the least in this project?

3. Has Weather-it community met your initial expectations?
4. Did you collaborate with other members in a mission? (yes)
5. How was the experience? (If no, what prevented you?)

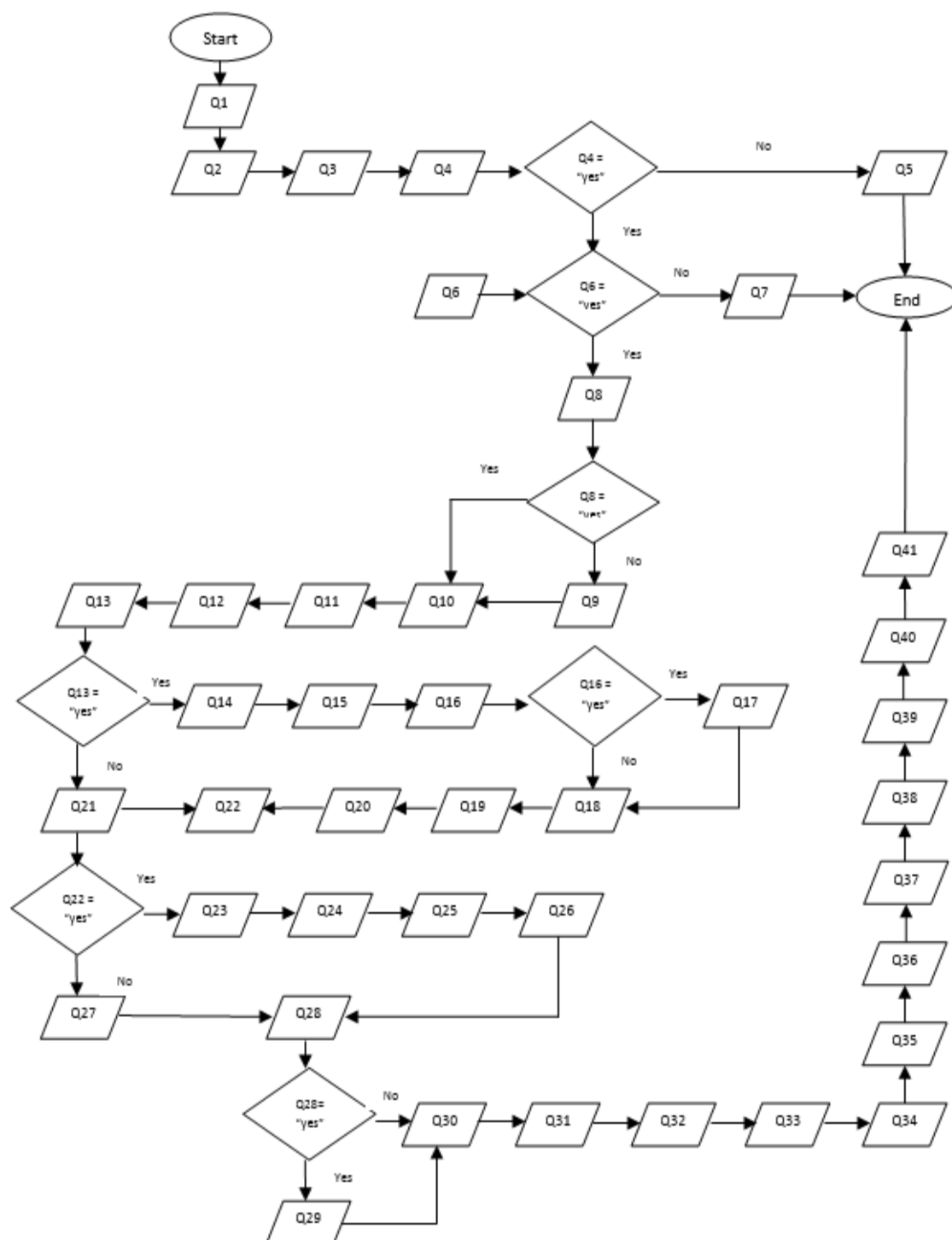
“yes”: how easy/difficult was it to create and maintain it?

“no”: Why?

6. <http://www.nquire.org.uk/journal>

You have participated in “Inquiring Rock Hunters”. Which project did you like the most and why?

7. Are you planning to stay on the platform for Weather-it or other missions?
8. Is there anything you would you like to change on nQuire-it?



1.

*** How did you learn about the weather-it project?**

- ☐ Facebook
- ☐ Twitter
- ☐ Email
- ☐ A friend
- ☐ Other (please specify)

2.

*** What motivated you to participate in this study?**

- ☐ The topic
- ☐ The software (nQuire-it and Sense-it)
- ☐ My friends
- ☐ Weather-it community
- ☐ Other (please specify)

3.

*** Describe your experience of Weather:**

- ☐ Beginner/amateur
- ☐ Intermediate
- ☐ Expert

Could you please expand on your response?

4.

*** Did you register with nQuire-it platform?**

☐ Yes

☐ No

5.

*** Could you please state the reason?**

6.

*** Did you visit the nQuire-it platform after your registration?**

☐ Yes

☐ No

7.

*** Could you please state the reason?**

8.

*** Are you still an active member of the community?**

☐ Yes

☐ No

9.

*** Could you please state the reason?**

10.

*** How often do/did you visit the community?**

- ☐ Many times a day
- ☐ Once a day
- ☐ Several times a week
- ☐ Once a week
- ☐ Several times a month
- ☐ Other (please specify)

11.

*** How much time do/did you spend on a typical visit?**

- ☐ 0-10 minutes
- ☐ 10-20 minutes
- ☐ Other (please specify)

12.

*** Over the most recent weeks how has the time you spent with the community compared with your first week?**

- ☐ More time
- ☐ Less time
- ☐ No change
- ☐ I am a new member

13.

*** Did you create a mission?**

- ☐ Yes
- ☐ No

14.

*** Which type of mission did you create?**

- ☐ Sense-it mission
- ☐ Spot-it mission
- ☐ Win-it mission

15.

Why did you prefer this type?

16.

* Did you invite people to your mission?

- ☐ Yes
☐ No

17.

How did you invite them?

18.

* Did you receive useful responses to your mission?

- ☐ Yes
☐ No

19.

* Did you conclude into a good answer?

- ☐ Yes
☐ No

20.

* Did you share the answers with the Weather-it community?

- ☐ Yes
☐ No

21.

*** Why?**

22.

*** Did you join other missions?**

- ☐ Yes
- ☐ No

23.

*** How many? (approx.)**

24.

*** Which type of mission (Sense-it, Spot-it, Win-it) did you prefer and why?**

25.

*** Did you add data? (pictures, sensor readings, etc.)**

- ☐ Yes
- ☐ No

26.

*** Did you invite other people? If so, how?**

27.

*** Why?**

28.

*** Do/did you communicate/collaborate in any way with other members of the community for a mission?**

- ☐ Yes
- ☐ No

29.

*** How? (Choose all that apply)**

- ☐ Comment on the mission
- ☐ Comment on data
- ☐ Forum
- ☐ Other (please specify)

30.

*** Do/did you find the help from the community useful? Please, write your comments.**

31.

*** Did you try to communicate but received no response?**

- ☐ Yes
- ☐ No

32.

*** Do/did you communicate/collaborate in any way with people outside the community for a mission?**

- ☐ Yes
- ☐ No

Comments:

33.

*** Do/did you feel like a part of the Weather-it community?**

- ☐ Yes
- ☐ No

Could you please expand on your response?

34.

*** When interacting within the Weather-it community and nQuire-it platform do you feel (please select all that apply):**

☐ distressed

☐ guilty

☐ jittery

☐ interested

☐ alert

☐ strong

☐ upset

☐ enthusiastic

☐ afraid

☐ active

☐ irritable

☐ determined

☐ scared

☐ inspired

☐ ashamed

☐ proud

☐ nervous

☐ excited

☐ hostile

☐ attentive

Comments:

35.

*** Would you stay a member of the community?**

☐ Yes

☐ No

Comments:

36.

*** What did you like the most in Weather-it?**

37.

What, if anything, have you learnt new or interesting through your participation in Weather-it?

38.

* Has Weather-it community met your initial expectations? Please, expand on your response.

39.

* With scale 1 (easy) – 10 (difficult), how easy did you find the use of nQuire-it platform?

1 (Easy)	2	3	4	5 (Moderate)	6	7	8	9	10 (Extremely difficult)
<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

40.


Do you have any suggestions for the improvement of the community or the nQuire-it platform?

41.

* Would you like to receive news for weather-it missions and nQuire-it platform, in the future?

☐ No, thanks.

☐ Yes, my email address is:



The Open University

From Dr Duncan Banks
Chair, The Open University Human Research Ethics Committee
Email duncan.banks@open.ac.uk^[1]
Extension 59198

To Maria Aristeidou, IET

Subject *"Inquiring Rock Hunters: investigating citizen inquiry through peer collaboration and informal mentoring by professional scientists."*

Ref HREC/2013/1415/Aristeidou/1

Red form

Submitted 08 April 2013

Date 17 April 2013


Memorandum

This memorandum is to confirm that the research protocol for the above-named research project, as submitted for ethics review, has been given a favourable opinion by the Open University Human Research Ethics Committee.

Please make sure that any question(s) relating to your application and approval are sent to Research-REC-Review@open.ac.uk quoting the HREC reference number above. We will endeavour to respond as quickly as possible so that your research is not delayed in any way.

At the conclusion of your project, by the date that you stated in your application, the Committee would like to receive a summary report on the progress of this project, any ethical issues that have arisen and how they have been dealt with.

Regards,



Dr Duncan Banks
Chair OU HREC

^[1] please note the change in email address



The Open University

From Dr Duncan Banks
Chair, The Open University Human Research Ethics Committee
Email duncan.banks@open.ac.uk
Extension 59198

To Maria Aristeidou, IET

Subject *"Weather Chasers: exploring the creation of self-sustained communities of scientific inquiries."*

Ref HREC/2014/1663/Aristeidou/1

AMS/RED

Submitted 17 March 2014

Date 26 March 2014

Memorandum

This memorandum is to confirm that the research protocol for the above-named research project, as submitted for ethics review, **has been given a favourable opinion** by the Open University Human Research Ethics Committee by **Chair's action** as it is thought to be low risk.

Please make sure that any question(s) relating to your application and approval are sent to Research-REC-Review@open.ac.uk quoting the HREC reference number above. We will endeavour to respond as quickly as possible so that your research is not delayed in any way.

At the conclusion of your project, by the date that you stated in your application, the Committee would like to receive a summary report on the progress of this project, any ethical issues that have arisen and how they have been dealt with.

Regards,

Dr Duncan Banks
Chair OU HREC

Do you like rocks?



Do you want to ask questions and find out more?



...Join us!

In a community...



Are the rocks on the beach different to ones on the mountain?



I have some rocks from this beach



I have some rocks from the mountain I went to yesterday. We can compare them.

with tools...



and experts!



For more information contact: Maria.Aristeidou@open.ac.uk

This project is part of my PhD research into citizen science inquiry

We are trying to understand and improve the engagement of citizens in scientific investigation and we would like you to help!

You can also find us on Facebook: <https://www.facebook.com/InquiringRockHunters> or visit our blog: <http://www.open.ac.uk/blogs/OIL/>



Do you like rocks and minerals? Would you like to ask questions about rocks and discover more about them?

My PhD project is to help people engage in scientific investigation, by giving them opportunities to collaborate with scientists and run their own research. For this study, I am exploring the involvement of amateur geologists in investigating rocks.

You will register with the online nQuire platform, which will guide you to design and run investigations of rocks. You will have the opportunity to form your own questions and methods, to reach appropriate conclusions. During your effort you will be supported by tools available on nQuire and also through communication with other participants.

The study will run between 13th - 27th May and you can visit the platform and spend there as much time as you want. Afterwards, you will have to complete two short questionnaires (5-10 mins each) within one week. In addition, if you agree, you can register to participate in a half an hour online discussion. The nQuire platform will remain active for you to carry on your inquiries.

If you are interested in taking part in my research, please do contact me for more information by 7th of May: Maria.Aristeidou@open.ac.uk or visit

- <http://www.open.ac.uk/blogs/OIL/>

- <https://www.facebook.com/InquiringRockHunters>

Thank you!

Maria



From: Maria.Aristeidou [<mailto:Maria.Aristeidou@open.ac.uk>]
Sent: 24 April 2013 16:44
To: 'sci-eee-all-list@open.ac.uk'
Cc: Mike.Sharpley (Mike.Sharpley@open.ac.uk); Eileen.Scannon@open.ac.uk
Subject: "Inquiring Rock Hunters"; Volunteers needed

Dear geologists,

I am a 1st-year PhD student in IET (Institute of Educational Technology) and I'm looking for your expertise!
I need volunteers to participate in my pilot study (a **citizen science** project) and act as **expert geologists** to help guide the public answer their geological questions themselves.

Below is a brief description of the study:
The aim of my PhD project is to help people engage in scientific investigation, by giving them opportunities to collaborate with scientists and run their own research. For this study, I am exploring the involvement of amateur geologists in investigating rocks.
Participants will register with the online nQuire platform, which will guide them to design and run investigations of rocks. They will have the opportunity to form their own questions and methods, to reach appropriate conclusions. During their effort they will be supported by tools available on nQuire and also through communication with other participants.
The study will run from 13th - 27th May and you can visit the platform and spend there as much time as you want. Afterwards, you will have to complete two short questionnaires (5-10 mins each) within one week. In addition, if you agree, you can register to participate in a half an hour online discussion. The nQuire platform will remain active for people to carry on their inquiries.

If you are interested in taking part in my research, please do contact me for more information.

Kind regards
Maria

Appendix M: Design Study 1 – Consent form and information sheet

Consent form for questionnaires with the participants of the “Inquiring Rock Hunters” project

The aim of my PhD project is to understand and improve the engagement of citizens in scientific investigation, by giving them the chance to collaborate with scientists and run their own research. For this study, I am exploring the involvement of amateur geologists in investigating rocks.

For the purposes of the study, you will register with the online nQuire platform, and nQuire will guide you to design and run investigations of rocks. You will have the opportunity to form your own questions and methods, to reach appropriate conclusions. The overall process ranging from the question formation to the conclusions is called an inquiry process. Your inquiry process will be supported by tools available on nQuire and also through communication with other participants.

The type of your inquiry will depend on your level of geology knowledge. For example, an inquiry could include a question relevant to general knowledge about rocks such as *“Why are some rocks light coloured and others not?”* or a more specialised question such as *“Where in Mohs scale [of mineral hardness] is chalk?”*. To progress the inquiry you will initially need to suggest some methods to work out your question, then during your inquiry you will have support from expert geologists, other participants and the tools. In addition to that, once you have posted your inquiry question, it will be shown on the forum as a new topic, where other people will be able to discuss or even join your inquiry as you can join theirs.

Prior to the study, you will be given the link to the nQuire tool and you will receive instructions on how to use it. The educational material will include some example cases of the tools in relation to the inquiry process and communication with other people. In this way, you will have the chance to test out some pre-prepared scenarios and have a foretaste of the tools, before the formal start date.

Approximately 15 days after the start date, you will be sent two short questionnaires of open and closed-ended questions and will be asked if you want to participate in an online focus group. The questionnaires and the online focus group will aim to investigate:

1. *The engagement of participants with the inquiry process:* the questions will be looking into how you understand and engage with the inquiry process, ranging from the question formation to the conclusion.

2. *The forms of the engagement:* the questions will focus on which methods and tools you prefer for your interactions.
3. *The effectiveness of nQuire tools on the participants' engagement:* the questions in this group will get your feedback on the nQuire tools in relation to their usability, effectiveness and desirability.
4. *The type of support the participants ask for and how they use it:* the questions will be examining "when", "where" and "from whom" you ask for help and support.

For the questionnaires: You will be sent the link to the online questionnaires and you will also be given a username and a password generated by the online survey tool. These details will be sent to you automatically by the online survey tool, after you provide your email address and you will need to use them to get access to the questionnaire.

For the Online Focus Group: The discussion will take place at the very end of this study. In case you want to take part in this, you will need to have or to create a Google+ account, as for the Online Focus Group we will use Google Hangout on Air. At your registration, you will be given the main topics for the discussion. The discussion will last for half an hour and will be recorded. The collected transcripts will be used for analysis, in an anonymous form.

The nQuire platform will remain active for you to carry on your inquiries.

At the end of the data analysis, you will be informed about the outcome of your participation and of the research, with a brief abstract of findings.

Important dates:

- 7 May 2013: Date for consent forms submission
- 14 May 2013: Launch of nQuire
- 20 May 2013: Date for Online Focus Group registration (send an email to Maria.Aristeidou@open.ac.uk)
- 28 May – 3 June 2013: Questionnaires
- 2-3 June 2013: Online Focus Group
- 4 June 2013: Deadline of withdrawal from the study
- September: Participants will be sent a summary of the findings

I, (print name in full)am over 18 years old and I agree to participate in this study being conducted as part of an Open University PhD research project.

I give permission for the data collected to be used in an anonymous form in any written reports, presentations and published papers relating to this study. My written consent will be sought separately before any identifiable data is used in such dissemination.

At any time during the research I am free to withdraw and to request the destruction of any data that has been gathered from me, up to the point, on 4th of June, at which data is aggregated for analysis.

I understand the purpose of the research, as explained in the covering information sheet, and accept the conditions for handling the data I provide.

Signature:

Date:

Maria Aristeidou, PhD Research Student

Institute of Educational Technologies, The Open University

Please return completed form to Maria.Aristeidou@open.ac.uk

Dear Rock Hunter!

The big day has arrived! Are you ready for your rock investigation?

nQuire platform:
The link to access the nQuire platform is: <http://137.108.65.18/nquire2/>
So you can now register and start your own research on rocks!

Instructions:
You can find some instructions on how to use the nQuire tool [here](#):
Password for the instructions: limestone
(The password is the same for all the pages)

Questionnaires:
Later on, you will be sent two questionnaires that you are kindly requested to fill in by 3rd of June.
The questionnaires are related to your experience with the inquiries, the interaction with the other participants and the nQuire platform.

Online Discussion:
If you have a Google+ account and you want to take part to the discussion, you can vote by 20th May for the day/time that is most convenient for you.
[English language](#)
[Greek language](#)

Your participation and your feedback are really important. You will help us to improve nQuire and create something better for us all to use!

I will be here for any questions you may have. Enjoy! J

Thank you!

Kind regards
Maria



My name is Maria Aristeidou and I am a PhD student at The Open University in UK. My supervisors are Professor Mike Sharples and Professor Eileen Scanlon. The aim of my PhD project is to understand and improve the engagement of citizens in scientific investigation, by giving them the chance to collaborate with experts, join missions, and run their own investigations. For this study, I am exploring the creation of a sustainable online community of weather missions.

This short questionnaire takes approximately 10 minutes and aims to investigate your engagement with the investigations and your experience within the community.

Your data will be used in an anonymous form in any written reports, presentation and published papers relating to this study.

At any time during the research you are free to withdraw and to request the destruction of any data that has been gathered from you, up to the point, 13th of March, at which data is aggregated for analysis.

At the end of the data analysis, I will inform you about the outcome of your participation and of the research, with a brief abstract of findings.

This research has been approved by the Open University Human Research Ethics Committee. If you have any questions about the research study, please contact:

Maria.Aristeidou@open.ac.uk


ELECTRONIC CONSENT: By selecting Agree below, you confirm the following:

- I am over 18 years old
- I understand the purpose of the research, as explained in the covering information sheet, and accept the conditions for handling the data I provide.
- I voluntarily agree to participate

*** Select:**

☐ Agree

☐ Disagree



1. Mission post (e.g. sensor post, spot-it image, win-it idea)

notification to the mission owner - straight away

Hello [usernameA](#),

You have received a new post from "[usernameB](#)" to your mission on "Weather-it" with the following subject:

"mission name"

You can view the mission post by clicking on the following link:

[link](#)

You can choose not to be notified of new messages by replying "unsubscribe" to this email.

--

Warm Regards,

nQuire-it team

2. Mission comment

a. notification to the mission owner - straight away

Hello [usernameA](#),

You have received a new mission comment from "[usernameB](#)" to your mission on "Weather-it" with the following subject:

"mission name"

You can view the mission comments by clicking on the following link:

[link](#)

You can choose not to be notified of new messages by replying "unsubscribe" to this email.

--

Warm Regards,

nQuire-it team

b. notification to the members who commented on this mission discussion too - twice a week (e.g. Monday & Thursday)

Hello [username](#),

There are new comments to the mission on "Weather-it" with the following subject:

"mission"

You can view the mission comments by clicking on the following link:

[link](#)

You can choose not to be notified of new messages by replying "unsubscribe" to this email.

--

Warm Regards,

nQuire-it team

3. Comment on a post (to a sensor post, spot-it image, win-it idea)

a. notification to the post owner - straight away

Hello [usernameA](#),

You have received a new comment from "[usernameB](#)" to your post on "Weather-it" with the following subject:

"post name"

You can view the comment by clicking on the following link:

[link](#)

You can choose not to be notified of new messages by replying "unsubscribe" to this email.

--

Warm Regards,

nQuire-it team

b. notification to the members who commented on the same post - straight away

Hello [username](#),

There are new comments to the post on "Weather-it" with the following subject:

"post"

You can view the comments by clicking on the following link:

[link](#)

You can choose not to be notified of new messages by replying "unsubscribe" to this email.

--

Warm Regards,

nQuire-it team

4. Forum post reply

a. notification to the thread owner - straight away

Hello [usernameA](#),

You have received a new forum post from "[usernameB](#)" to your post on "Weather-it" with the following subject:

"thread topic"

You can view the forum posts by clicking on the following link:

[link](#)

You can choose not to be notified of new messages by replying "unsubscribe" to this email.

--

Warm Regards,

nQuire-it team

b. notification to the members who posted on the same forum thread- straight away - twice a week (e.g. Monday & Thursday)

Hello [username](#),

There are new forum posts to the post on "Weather-it" with the following subject:

"thread topic"

You can view the forum posts by clicking on the following link:

[link](#)

You can choose not to be notified of new messages by replying "unsubscribe" to this email.

--

Warm Regards,

nQuire-it team

Appendix R: Design Study 2 – Engagement metrics per Weather-it member

Member	Activity ratio	Relative Activity duration	Lurking ratio	SD periodicity
Abroholos	1.000	0.011	0.000	
Altocumulus	0.063	0.235	0.500	
Altostratus	0.000	0.033	1.000	
Arcus	0.095	0.808	0.333	0.000
Austru	0.147	0.969	0.263	13.331
Bali	0.500	0.023	0.000	
Barat	0.094	0.928	0.250	4.224
Barber	1.000	0.011	0.000	
Bayamo	1.000	0.036	0.000	
Bora	0.778	0.091	0.000	1.118
Boreas	0.393	1.000	0.111	2.021
Brisa	0.098	0.979	0.100	12.298
Brisote	0.046	0.756	0.250	21.500
Brubu	0.092	0.946	0.200	7.871
Chinoo	0.054	0.402	0.333	0.000
Chubasco	0.444	0.818	0.200	1.247
Cirrocumulus	0.200	0.714	0.250	5.437
Cirrostratus	0.000	0.030	1.000	
Cirrus	0.111	0.692	0.000	10.654
Contrail	0.500	0.025	0.500	
Contrastes	0.000	0.012	1.000	
Cordonazo	0.000	0.013	1.000	
Coromell	0.000	0.012	1.000	
Cumulonimbus	0.000	0.111	1.000	
Cumulus	0.414	0.983	0.200	1.763
Cyclone	1.000	0.011	0.000	
Diablo	0.116	0.750	0.273	12.960
Drought	0.111	0.692	0.500	2.000
Etesian	0.375	0.083	0.000	0.500
Euros	1.000	0.333	0.000	
Fallstreak	0.000	0.036	1.000	
Foehn	0.500	0.077	0.500	
Fremantle	0.500	0.071	0.000	0.000
Funnel	0.250	0.421	0.000	0.000
Gregale	0.014	0.780	0.800	
Haboob	0.071	0.918	0.000	15.370
Harmattan	1.000	0.012	0.000	
Lenticular	1.000	0.029	0.000	
Leste	0.593	0.276	0.158	0.895
Levantera	0.000	0.012	1.000	
Levanto	0.278	0.551	0.167	5.199
Maestro	0.000	0.044	1.000	

Mammatus	0.000	0.200	1.000	
Matanuska	0.333	0.032	0.500	
Mistral	0.636	0.113	0.000	0.471
Mushroom	1.000	0.012	0.000	
Nacreous	1.000	0.029	0.000	
Nashi	0.224	0.630	0.000	6.029
Nimbostratus	0.000	0.036	1.000	
Noctilucent	0.000	0.050	1.000	
Norte	0.295	0.979	0.152	3.507
Norther	1.000	0.026	0.000	
Ostria	0.263	0.969	0.074	3.998
Pali	0.083	0.264	0.333	0.000
Pampero	1.000	0.011	0.000	
Papagayo	0.017	0.789	0.667	
Santa-Ana	0.182	0.710	0.500	6.128
Shamal	0.222	0.957	0.048	7.928
Sharki	0.083	0.980	0.529	12.068
Sirocco	0.250	0.098	0.000	0.000
Squamish	0.000	0.091	1.000	
Stratocumulus	0.000	0.038	1.000	
Stratus	0.459	0.949	0.105	1.256
Suestado	1.000	0.012	0.000	
Sumatra	0.000	0.012	1.000	
Sundowner	0.068	0.898	0.250	14.500
Tahuantepecer	0.000	0.011	1.000	
Taku	0.625	1.000	0.167	0.829
Tramontana	0.086	0.988	0.300	5.620
Typhoon	0.163	0.956	0.176	6.811
Undulatus	0.556	0.818	0.000	0.707
Vardar	0.400	0.102	0.000	1.633
Virga	0.048	0.677	0.000	0.000
WarmBraw	0.150	0.800	0.250	9.500
White-Squall	0.000	0.026	1.000	
Williwaw	0.195	0.951	0.000	9.745
Zephyros	0.313	0.980	0.118	0.480
Average	0.318	0.415	0.351	5.112
SD	0.347	0.401	0.387	5.362

Appendix S: Design Study 2 – Clustering of members in engagement profiles

Member	Engagement profile	Cluster	Distance from cluster centre
Abroholos	Visitors (observing)	5a	0.079
Altocumulus	Visitors (active)	5b	0.231
Altostratus	Visitors (hesitant)	5c	0.012
Arcus	Visitors (active)	5b	0.435
Austru	Persistent	2	0.191
Bali	Visitors (observing)	5a	0.429
Barat	Lurker	1	0.257
Barber	Visitors (observing)	5a	0.079
Bayamo	Visitors (observing)	5a	0.072
Bora	Hardworking	3	0.228
Boreas	Loyal	4	0.088
Brisa	Persistent	2	0.239
Brisote	Persistent	2	0.28
Brubu	Persistent	2	0.27
Chinoo	Visitors (active)	5b	0.137
Chubasco	Loyal	4	0.139
Cirrocumulus	Lurker	1	0.107
Cirrostratus	Visitors (hesitant)	5c	0.015
Cirrus	Persistent	2	0.29
Contrail	Visitors (active)	5b	0.495
Contrastes	Visitors (hesitant)	5c	0.033
Cordonazo	Visitors (hesitant)	5c	0.033
Coromell	Visitors (hesitant)	5c	0.033
Cumulonimbus	Visitors (hesitant)	5c	0.066
Cumulus	Loyal	4	0.141
Cyclone	Visitors (observing)	5a	0.079
Diablo	Persistent	2	0.181
Drought	Lurker	1	0.242
Etesian	Hardworking	3	0.194
Euros	Visitors (observing)	5a	0.297
Fallstreak	Visitors (hesitant)	5c	0.009
Foehn	Visitors (active)	5b	0.459
Fremantle	Visitors (observing)	5a	0.429
Funnel	Visitors (active)	5b	0.38
Gregale	Visitors (active)	5b	0.607
Haboob	Persistent	2	0.297
Harmattan	Visitors (observing)	5a	0.079
Lenticular	Visitors (observing)	5a	0.073
Leste	Hardworking	3	0.194
Levantera	Visitors (hesitant)	5c	0.033
Levanto	Lurker	1	0.267
Maestro	Visitors (hesitant)	5c	0.001
Mammatus	Visitors (hesitant)	5c	0.155

Matanuska	Visitors (active)	5b	0.403
Mistral	Hardworking	3	0.096
Mushroom	Visitors (observing)	5a	0.079
Nacreous	Visitors (observing)	5a	0.073
Nashi	Loyal	4	0.366
Nimbostratus	Visitors (hesitant)	5c	0.009
Noctilucent	Visitors (hesitant)	5c	0.005
Norte	Loyal	4	0.188
Norther	Visitors (observing)	5a	0.074
Ostria	Loyal	4	0.228
Pali	Visitors (active)	5b	0.162
Pampero	Visitors (observing)	5a	0.528
Papagayo	Visitors (active)	5b	0.474
Santa-Ana	Lurker	1	0.212
Shamal	Persistent	2	0.295
Sharki	Persistent	2	0.357
Sirocco	Visitors (active)	5b	0.474
Squamish	Visitors (hesitant)	5c	0.046
Stratocumulus	Visitors (hesitant)	5c	0.007
Stratus	Loyal	4	0.073
Suestado	Visitors (observing)	5a	0.079
Sumatra	Visitors (hesitant)	5c	0.033
Sundowner	Persistent	2	0.237
Tahuantepecer	Visitors (hesitant)	5c	0.035
Taku	Loyal	4	0.249
Tramontana	Persistent	2	0.249
Typhoon	Persistent	2	0.108
Undulatus	Loyal	4	0.218
Vardar	Hardworking	3	0.19
Virga	Visitors (active)	5b	0.493
WarmBraw	Persistent	2	0.23
White-Squall	Visitors (hesitant)	5c	0.019
Williwaw	Persistent	2	0.307
Zephyros	Loyal	4	0.152