Design processes of a citizen inquiry community

Book Section

Design processes of a citizen inquiry community

Maria Aristeidou, Eileen Scanlon and Mike Sharples
{Maria.Aristeidou; Eileen.Scanlon; Mike.Sharples}@open.ac.uk
Institute of Educational Technology, The Open University

Abstract

As with other online communities, it is important to design elements of citizen inquiry projects that will attract and engage members. This chapter describes the process of designing an online community for citizen inquiry. It builds on design principles of inquiry learning, citizen inquiry and other online communities. The 'Weather-it' citizen inquiry community is intended to engage and support people in initiating and joining sustainable citizen-led investigations. The findings indicate some successful mechanisms for the design of effective and sustainable citizen inquiry communities and ways to sustain them.

Introduction

As citizen science projects develop and spread, human-computer interaction (HCI) researchers are focusing on how to improve the user experience, attract more members and amplify scientific and learning outcomes in projects with IT infrastructure (Preece, 2016). The need to design and implement user-centred technologies was one response to the high attrition rate (Nov, Arazy, and Anderson, 2011a, 2011b; Ponciano and Brasileiro, 2015) and the dabbling behaviour of the members who are not deeply engaged (Eveleigh et al., 2014) noted in these communities. What distinguishes the design of citizen inquiry from citizen science design is its emphasis on advancing the collaborative inquiry learning aspects of the project and supporting citizens to initiate their own investigations. Although the community design focus is on taking engagement and user experience to a greater level, it is also important to realise that we are creating community learning and inquiry spaces. The aim of this chapter is to identify some design features for engaging members in online citizen inquiry communities whilst also supporting inquiry learning within them. This may lead to a design which offers better scaffolding and offers guidance in every inquiry step to support citizen-led investigations within an engaging and sustainable environment. Given the multi-faceted nature of online citizen inquiry communities, this study is framed around four topics: online communities, inquiry learning, design, and technology. The organisation of the chapter is as follows. The following section briefly introduces the four aforementioned challenging topics. We then summarise how requirements drawn from these areas were implemented on the nQuire-it platform, tested with an online citizen inquiry community (Weather-it) and compared to another community (Inquiring Rock Hunters). Next, we reflect on the design results and propose guidelines for improving community engagement and inquiry learning in similar citizen inquiry communities, based on the outcomes of the interventions. The last section presents conclusions from this study.

Background

Online communities

The main idea of citizen inquiry is to open up social scientific processes to distributed communities of citizens with shared interests to allow them to conduct and report the results of inquiry-led projects. These communities operate mainly online because their members are geographically distributed. An online community is any virtual social space that has a purpose, is supported by technology and is guided by shared policies (e.g., registration policies, language) (Preece, 2001). What distinguishes online communities, in general, from other software is the interactions among people; they come together to learn, give or receive information and support, and find company. In this chapter, we discuss the nQuire community for citizen inquiry, where members of the public create small-scale science investigations for others to contribute, on topics that have included weather and environmental noise. Other examples of citizen inquiry communities include iSpot (Silvertown, 2015) and Zydeco (Lo et al., 2013). What characterises these communities is a prime focus on science learning through shared inquiry.

Activating the majority of the members and trying to get them to be active contributors instead of lurkers (not active contributors) is significant for achieving the critical mass of members and member-generated content in the community. 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). A theory that supports this work is the *three-component model of commitment* (Meyer & Allen, 1991), which was developed to reflect the different psychological stages that support and attach the members to communities. These correspond to the psychological states of *affective*, *normative* and *continuance* commitment. In *affective commitment,* members 'want to stay'. This is divided into 'identity-based' commitment, where the member is a part of the community, and 'bond-based' commitment, where the member is close to the other members. In *normative commitment,* members 'ought to stay' and is associated with the commitment to the purpose of the community, the commitment of other members and the reciprocity. In *continuance commitment*, members 'need to stay' and refers to the net benefits people gain from the community, such as information, social support, companionship and reputation (Ridings & Gefen, 2004). Some design examples that strengthen commitment are to increase the sense of co-presence (Slater et al., 2000) and interpersonal interaction (Postmes, Spears & Lea, 2002) (affective), to highlight the purpose and up-to-date success of the community (Ren & Kraut, 2012) (normative), and to assess motivations for participating in the community (Ghosh, 2005; Nov, 2007) (continuance).

Examining the lifecycle of an online community by observing its activities and growth, such as those we wish to develop for citizen inquiry, helps in monitoring the community and adjusting the approaches used within it in order to keep it active (Iriberri & Leroy, 2009). At each stage the members have different needs and it is necessary to employ different tools, technologies or management activities efficiently. One description of the lifecycle of a typical online community consists of the following stages: potential, coalescing, maturing,

stewardship and transformation (Wenger, McDermott, & Snyder, 2002). This 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 (Iriberri & Leroy, 2009) or with fewer stages, such as pre-birth, early life, maturity, death (Preece, 2000). Although there are suggestions available at every stage of the lifecycle for sustaining the community, the communities never 'run themselves' even if the fundamental design has been set in motion from the early stage of their development. Community leaders interviewed argue that a community is never completely 'built' (Stuckey & Smith, 2004) and research shows that ongoing design and development depends on the individual community and its own community life (Fischer, 2002; Aristeidou, Scanlon, & Sharples, 2015b).

Inquiry learning

In citizen science projects, members of the public take part in scientifically-valid investigations and may experience the process of scientific discovery. In this way, they may learn about the research topic and develop scientific literacy. According to evidence-based research by Kloetzer et al. (2013), three levels of learning can be identified in citizen science 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). This learning occurs both informally, through contributing to the task and interacting with others, and formally, with scientists providing training to members for completing specific tasks.

However, learning in citizen science projects happens mainly as a side effect during the formalised training which aims at successful completion of the scientific goals, rather than as part of an educational design that intends to improve the learning outcomes. This training is focused on the skills required to perform the specific investigation. 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. This limited evidence of participant gains in knowledge about science knowledge and process (Bonney et al., 2015) along with a lack of evidence that citizen science projects have been effective in meeting educational goals (Crall et al., 2013) have led to the development of citizen inquiry communities that put a greater emphasis on designing for learning.

Blending inquiry learning with citizen science in a citizen inquiry community leads to the creation of an environment of bottom-up citizen participation, where citizens need a scaffolding mechanism to conduct their own personally meaningful and authentic investigations. Thus, creating an online environment for citizen inquiry requires difficult design decisions, as the interactions need to be supported and guided. An inquiry-led system addresses suggestions from previous studies on learning in citizen science projects, towards putting the material to be presented in the context of the scientific method (Cronje et al., 2010; Crall et al., 2012). For instance, seeing a dynamic representation of the inquiry process could allow members to shape the processes of investigation and understand how these align with inquiry activities. Such a

representation conveys a simple navigation that supports the cycle of inquiry, with its phases, tools and activities. An example is the inquiry phase diagram (octagon) (Figure 1) from the Personal Inquiry project, designed for structuring inquiry, supporting discussion and enabling sharing of results (Sharples & Anastopoulou, 2012). The inquiry cycle 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'.

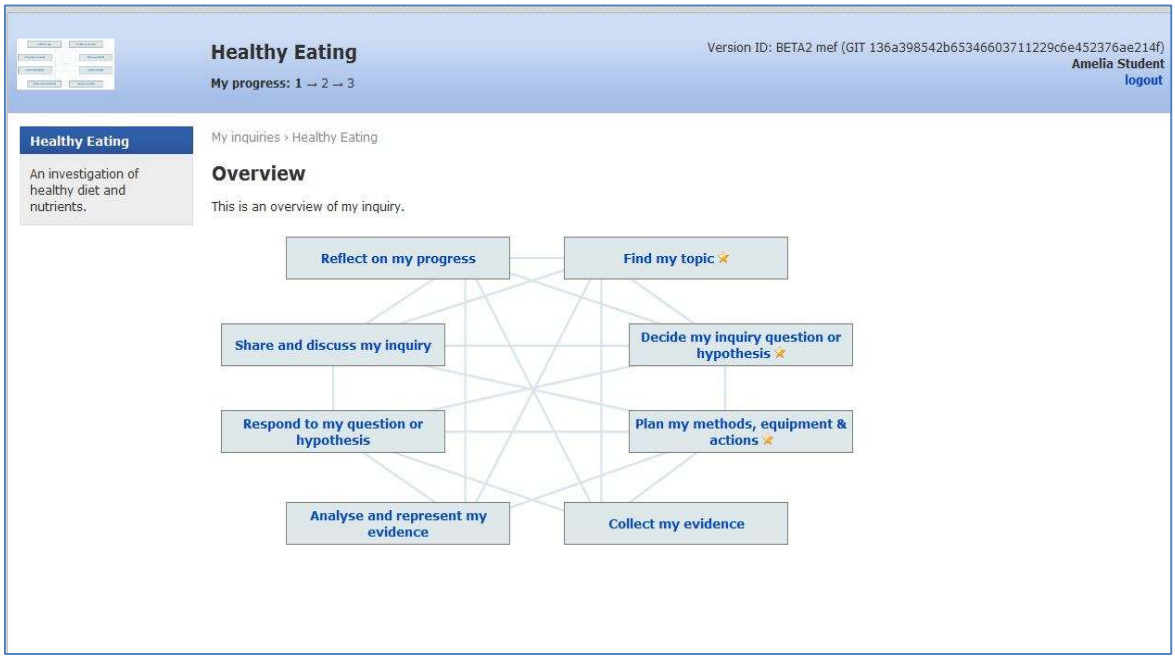

Figure 1: The inquiry phase diagram from the Personal Inquiry project

Design

As mentioned earlier, the design of a citizen inquiry community should reflect members' needs and experiences. One of the most important concerns is usability design, especially when you have to design for people with different technology experiences. After securing the technology usability, an important task is to understand how communities form around citizen inquiry projects and how to support community members. Approaches to the creation of technologies that focus on users and their needs are 'participatory design' (Kensing & Bloomberg, 1998; Schuler & Namioka, 1993) 'crowdsourced design' (Grace et al., 2014; Maher et al., 2014) and 'human-centred design' (Sharples et al., 2006; Steen, 2011). Participatory design involves collaboration between technology designers and users in order to place the latter as partners in the centre of design decision-making. In crowdsourced design, users are invited to express their opinion about the design and suggest changes that may improve it and meet their own needs. Finally, in human-centred design experts' knowledge of system design, human cognition and social interaction are combined with studies involving typical users, to inform design.

Creating a community for citizen inquiry requires development of tools and practices that can be adopted by diverse groups of people and support the facilitation of inquiries. A starting point

for developing such a community is exploring design aspects of online communities and inquiry learning practices mentioned in the previous sections. Therefore, some important steps could be taken for the community pre-birth preparations, such as the selection of technology, community and inquiry requirements, setting up exemplar inquiries, and testing the tools used for the investigations. Then, a core group could give life to the community, recruit and welcome new members. Finally, several techniques could be used for making the community more appealing and thereby sustain participation, such as get started instructions, prizes, email updates, and notifications. The community design can eventually be improved in the next iteration through design contributions submitted by members, who in turn gain social rewards as the system evolves (Fischer, 2011) and become satisfied with a design that meets their needs.

Technology

Networked technology opens the door for broad public participation and facilitates the operation of projects in which members are geographically distributed. The user experience of members taking part in citizen science projects can be enhanced by using integrated platforms that use additional data collection technology, such as camera, sensor and geo-positioning software, distributed by Google Play Store, Apple Store and other online app stores. But making good technology choices requires answering some key questions: What type of project will it be used for (type of data collection/analysis required) and who are the members?

In citizen inquiry communities, as in other online communities, there is a diversity of members, in terms of nationality, language, interests, experience and age. Some members will be familiar with new technologies; others will be experts in the scientific topic. While top-down citizen science projects are grouped into 'active' and 'passive' data collection projects, based on whether they actively involve humans in collecting data (Preece, 2016), citizen inquiry communities engage members in actively conducting their own investigations based on their everyday experience of science. Thus, the technology should not be limited to data collection and analysis, but should offer space for initiation, incubation, sharing, visualization, discussion and personalization of science investigations, so that non-expert participants can design and structure inquiries, and recruit other people to take part, assisted by more expert members or through help functions embedded in the technology. Other activities that take place in citizen inquiry communities, similar to citizen science projects, include contributing data to one's own or other investigations, reviewing, discussing, and analysing contributions, and re-using data for other purposes such as teaching. Designing technology that supports inquiry and discussions, ensures smooth operation of activities and motivates members is important for enabling learning and engagement.

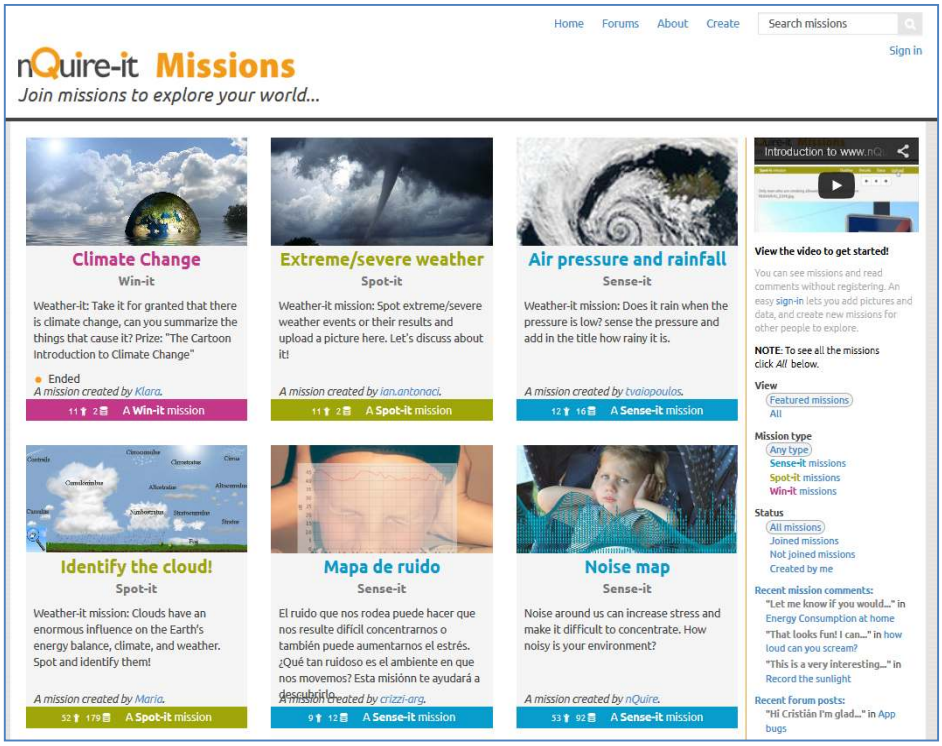

Figure 2: The nQuire-it platform

A team from the UK Open University, inspired by the citizen inquiry approach, created the nQuire toolkit, which supports the idea of having lay people act as scientists (Herodotou, Villasclaras-Fernandez, & Sharples, 2014). The nQuire toolkit building on previous work on the nQuire platform designed to support inquiry learning in schools (Sharples et al., 2015) scaffolds members in creating, managing, sharing and completing projects of their own interest. It consists of the nQuire-it web platform[1] (Figure 2) and the Sense-it Android app[2] (Figure 3). Based on the method of data collection, the nQuire-it platform provides three different types of investigation (called 'missions'): Sense-it, Spot-it and Win-it. Sense-it missions use sensor recordings collected from the Sense-it Android application; Spot-it missions display user-contributed pictures for discussion and comparison; Win-it missions pose research questions which require text for answers. The Sense-it Android app activates the existing sensors of Android smartphones and tablets, such as light sensor, humidity, pressure and temperature. The Sense-it app profiles connect to Sense-it investigations on the nQuire-it platform. Users record, visualise, store, and download the log files on their mobile devices or upload them to the platform.

[1] www.nquire-it.org
[2] https://play.google.com/store/apps/details?id=org.greengin.sciencetoolkit

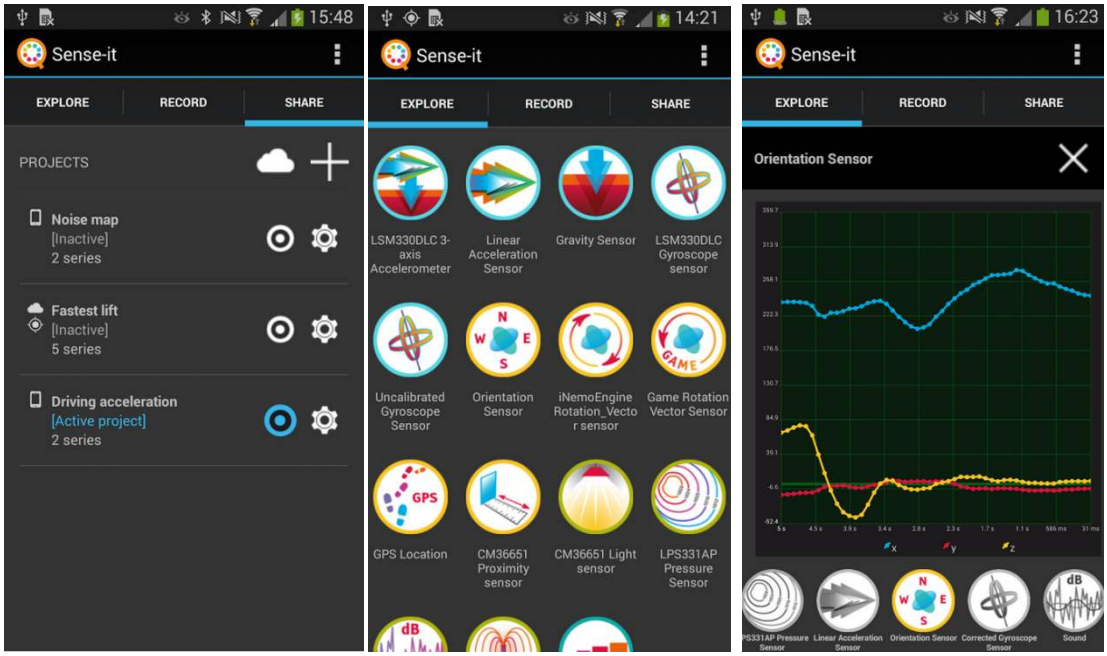

Figure 3: Screen displays from the Sense-it Android app at Google Play

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. 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 through combination and synthesis of multiple contributions from the members, utilizing in this way 'collective intelligence' (Suriowecki, 2005). 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. The source codes for the nQuire-it platform and Sense-it app are available3 for modification and distribution.

Methodology

Design-based research

In this chapter we describe some design features for engaging members in citizen inquiry communities and advancing inquiry learning within them. The current study employs a design-based research methodology (Design-Based Research Collective, 2003). Design-based research stresses the need for design principles that inform and enhance both research and practice in educational contexts, and leads to the development of usable knowledge. A central notion in design-based research is to create an improved practice, while the 'intervention' is a collaborative task of both the research and the participants (Cobb et al., 2003). In this regards, we chose this particular methodology in order to study the interventions through ongoing revisions according to the success of the revisions on levels of engagement and learning, and identify all the aspects that may affect the situation rather than manipulating specific variables

[3] *https://github.com/nQuire*

(Collins et al., 2004). We have also employed crowdsourced design (Maher et al., 2014) in order to capture participants' perceptions and suggestions about the design and improve it accordingly.

This research employed two design studies around the citizen inquiry communities: 'Inquiring Rock Hunters' and 'Weather-it'. In the first community, members were conducting investigations about rocks and in the second about weather. The first intervention design, Inquiring Rock Hunters, had a more exploratory character and thus, allowed room for improvements in the design of the second longer iteration. Results from the first intervention (with 24 participants) showed that there was a low sense of belonging to the community and low levels of engagement (Aristeidou, Scanlon, Sharples, 2014). Therefore, the main requirements for building the second intervention, Weather-it (with 101 participants), focused on the design of an engaging citizen inquiry community that facilitates inquiry learning. Nevertheless, we can draw implications from both interventions for orchestrating a citizen inquiry community.

Detailed results of the projects have been presented elsewhere (Aristeidou, Scanlon & Sharples, 2014; Aristeidou, Scanlon & Sharples, 2015a; 2015b); this chapter describes design features applied mainly to Weather-it community (and in comparison to some Inquiring Rock Hunters results), that engage and disengage citizen inquiry community members, and increase inquiry learning within the communities. These prepare other practitioners to further advance online citizen inquiry and other similar communities.

Methods used for data collection

The data collection employed open-ended survey questions and it was aiming at gaining insight into the satisfaction and learning levels of the community members. Qualitative analysis of the data involved consideration of all the responses in the survey questions: *"What did you like the most in Inquiring Rock Hunters/Weather-it?"* (n1=20, n2=52)., *"Are you still an active member of the Weather-it community (and answer = no), could you please state the reason?"*(n=17) and *"What, if anything, have you learned new or interesting through your participation in Inquiring Rock Hunters/Weather-it?"* (n1=20, n2=28). Thematic analysis and inductive coding of the responses from the first two survey questions allowed the development of themes focused on design factors that engage and disengage members from the communities, respectively, while responses to the third question provided insight into the design features, of the particular community, that supported learning. The approach used in orchestrating the design of the communities is described in the next section.

Proposed orchestration of the citizen inquiry community

Our approach to designing the citizen inquiry communities has been guided by the needs of citizen inquiry and advice around online communities, and has been improved through crowdsourced design. Design resources we needed to consider included collaborative inquiry tools, learning content, data collection tools, uses of mobile sensors and social technologies.

Building on an already-existing citizen inquiry platform (nQuire-it), some of the requirements had already been included in its design (see 'Existing nQuire-it design' section below), so the focus was on improving it and making it more engaging. Essential requirements to be implemented are listed in Table 1, followed by less essential ones, in the 'Design requirements' section below. The section 'Requirements applied to nQuire-it' demonstrates the requirements that were finally implemented.

Existing nQuire-it design

Some principles influencing the initial design of the nQuire-it platform included the following:

- *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) on the home page.
- *Create a profile (username, photo, and country/town).* Wenger (2001) argues for the importance of individual identity in a social learning system. The users should be able to express their individual personality in the community by adding personal information and 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 from other platforms.* The integration of the community with other sites, such as Facebook, Google and Twitter makes user registration easy and fast by using their existing user identifiers.
- *Search, join and start a mission.* Searching, joining and starting missions are essential requirements for citizen inquiry communities and nQuire-it offers easily-accessed buttons to facilitate these options.
- *Inquiry-led mechanism.* The platform provides guidance for the investigations through steps and tabs that represent inquiry phases.
- *Comment on data (Figure 4).* This feature allows feedback and discussion around the collected data.

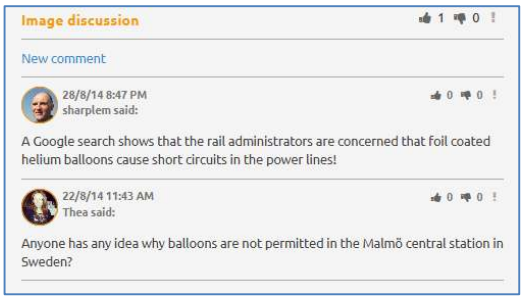

Figure 4: Quire-it – comment

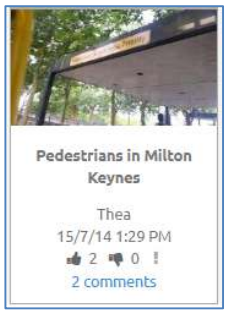

Figure 5: nQuire-it – thumb up

- *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 (Iriberri & Leroy, 2009). The current reward system in nQuire-it is based on receiving or giving 'likes' (Figure 5).
- *Links to forums* to join the platform forum discussion. The forums can be used for on-topic and off-topic discussion, and for direct communication between members and moderators.
- *Archive list* with all the investigations or by specific type. A list with all the available investigations makes it easier for the members to view and participate in those that reflect their interests.

Design requirements

The following table presents a list with the essential additional requirements to be implemented:

Table 1: Essential design requirements

Requirement name	**Description**	**Reference**
Notification	to reinforce participation	Kraut & Resnick, 2011
List with recent investigations	to help members find the most active investigations	Resnick & Konstan, 2012
News feed	to convey activity within the community	Resnick et al., 2012
Personal messages	to build stronger relationships	McKenna et al., 2002
Top posters	to build a comparative atmosphere and motivate members	Locke & Latham, 2002
Most popular investigations	to display performance feedback and motivate members	Kraut et al., 2012
Who is currently online	to increase social presence interaction and engagement	(Preece, 2000), (Beuchot & Bullen, 2005) (Brown, 2001)
Invitations through other social networks	to attract members to the community	Resnick et al., 2012
Visit profiles	to increase co-presence	Slater et al., 2000
Web analytics	to trace and demonstrate community statistics to the moderator	Resnick et al., 2012
Video tutorial	to introduce new users to the platform	

Other less essential requirements to be implemented, extracted or drawn from literature, include *badges* for particular contributions (Anderson et al., 2013) and the *reader-to leader funnel* (Preece & Shneiderman, 2009), which causes progressive commitment as the newcomers move from being reading to having leadership roles within the community; *members' list* and *location map* for social presence; *add friends* for enhanced affective commitment; *subscription* to mailing list for community updates (Kraut & Resnick, 2011); *feedback* in every step of the investigation (Kubey & Csikszentmihalyi, 2013); and a *learning room* for further discussions, as in some online community forums (e.g., UK Weather Watch).

Requirements applied to nQuire-it

Only a subset of the above requirements was implemented on the nQuire-it platform due to limitations in time and resources and privacy and security concerns. The applied features (see list below) were mainly drawn from the above list of essential requirements or emerged from 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 according to project requirements.

- 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 6).

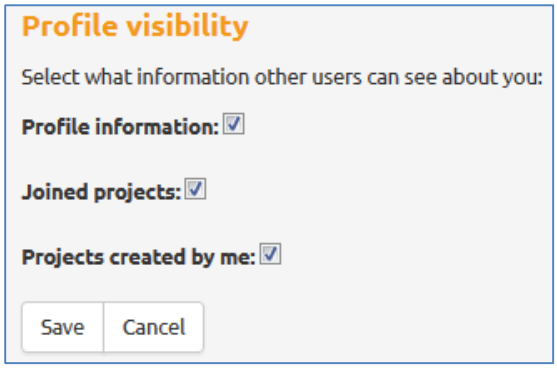

Figure 6: nQuire-it profile visibility

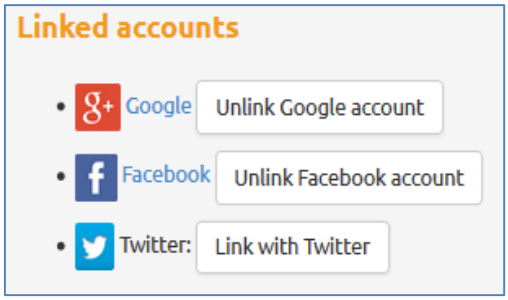

Figure 7: nQuire-it linked accounts

- 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.
- *Web analytics* were accessed through the Google analytics page and facilitated monitoring the activity within the community daily and weekly.

- A *learning room* was developed in the forums, where further discussion took place around the investigations and other topic-related issues.
- *Exemplar investigations* of each mission type were set up, with input from topic experts, in order to be used as examples for the creation of other missions
- 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 7).
- Another feature which is considered significant for a community for 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.

Alternative techniques were sought for some other important features that could not be implemented on the platform for this project. These include:

- Tangible *awards and prizes* (amazon coupons and books) for particular contributions, such as monthly prizes for the top contributor, best photographer and the most voted Win-it response.
- Manual *notifications* to the members for any feedback received on their posts.
- A *mailing list* with the new activities and weekly updates, and a Facebook group with daily posts which aimed to remind the members to visit the community again.

Reflections on the design

In Inquiring Rock Hunters which was based on an earlier platform, most of the members commented on the difficulty they would have had to use the software without a tutorial. The Weather-it mission on the nQuire-it platform was generally found to be easy to use, with some members commenting on the well-organised structure, and the ease of browsing subjects and creating missions. However, several members spotted software bugs or limitations during or at the end of the project. 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. The majority of the Weather-it members referred to the technology and software usability 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.

Overall, and beyond technology, the factors that sustained the engagement of members who remained active in the Weather-it community until the end of the project as identified in the survey responses, were the social aspect, the variety, and the concept of citizen inquiry (investigation ownership and interaction). On the other hand, the disengagement of Weather-it members from the community was mainly related to time constraints and secondly to lack of interest in the available topics. 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.

The majority of Inquiring Rock Hunters stated that throughout their participation in the community, beyond content knowledge, they also gained knowledge on how to approach an investigation. 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 reports from Weather-it members in which they mentioned that they gained domain knowledge, yet they made no reference to learning about research methods and science inquiry process. A strong influence on the Weather-it outcome is likely to be the absence of the visualised inquiry framework used in Inquiring Rock Hunters. Finally, findings related to the Weather-it evolution and sustainability indicated that the ongoing design and development, based on the individual community and its needs as applied in this work, resulted in eventually having a slightly growing and sustainable community with steady activity fluctuations (Aristeidou, Scanlon, Sharples, 2015b). It is still an open issue as to whether is possible to sustain a community of citizen inquiry in the long term, beyond the period of active design and facilitation.

Implications for the design of a citizen inquiry community

The following design considerations aim to facilitate the creation, improvement and sustainability of online citizen inquiry communities in which members remain engaged and adopt good inquiry learning practices. These do not aim to apply to all contexts, but to improve the design of online citizen inquiry communities and their scaffolding mechanisms for the creation of collaborative, personally meaningful and authentic investigations by citizens.

Support ongoing feedback on software. The importance of the technology usability has been emphasised in this study, as this was reported as the main reason for members to stay or leave the community. It is, therefore, important to address usability concerns by engaging members in the evolving design. Ongoing feedback may reveal bugs and needs, improve the software design, and obviate member dropouts.

Support variety in topics and ways of engagement: Community members commented positively on the variety within our citizen inquiry community. In nQuire-it, variety was enriched not only through the data collection methods that missions provided, but also with the diversity in topics, locations, and members' level of expertise that made participation more interesting. This idea of multiple forms of contribution acknowledges the many interests of users and motivates members' participation (Bonney et al., 2015).

Provide social technologies. Our findings illustrate that some members sustained participation in the community and developed a sense of belonging due to the interactions they had with other members during their investigations. The nQuire-it toolkit supported interactions between members through an open participation approach which is suggested to enhance the sense of community and lead 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.

Support ownership of collaborative investigations. Members of the citizen inquiry community showed their satisfaction with the option to create their own missions or help others with their missions. Unlike other citizen science projects where volunteers were more interested in solitary experience and independent working (Eveleigh et al., 2014), Weather-it members found interaction a fun way of learning and getting engaged with science.

Update members with to-do lists of smaller or similar tasks. Drop-outs are 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 could support their return.

Promote support groups. Another important reason why members stopped engaging with the community was lack of confidence. Members' anxiety about the quality of their contributions may be overcome with the creation of experts supporting groups that discuss the data and comment on contributions.

Design explicit inquiry activities as part of a complete scientific process. Members of Inquiring Rock Hunters indicated higher levels of scientific literacy gains compared to Weather-it members. A design feature that facilitated understanding of inquiry phases and methods was the use of the inquiry framework (see Figure 1) that allowed members to understand the structure of the inquiry activities. Engaging members with several phases or the entire scientific process requires preparation. It is necessary to provide aim, activity, tools and research method instructions for each phase. This information about the entire scientific process and where each inquiry phase lies may facilitate scientific literacy to a greater extent. However, there may be a tension between providing well-structured activities and supporting easy creation of a broad range of missions and challenges by users. The first may lead to gains in knowledge of scientific processes, but at the expense of user engagement and participation, and the latter may result to lack of scientific rigour.

Concluding comments

In this chapter we have reviewed the literature that frames our work on citizen inquiry communities, with a particular focus on which aspects support engagement and enhance inquiry learning in the community. We have demonstrated design requirements, drawn or borrowed from literature, that aim at improving the orchestration of citizen inquiry communities. Of those requirements, several were implemented and tested on nQuire-it through the *Weather-it* citizen inquiry community, and the results were compared to *Inquiring Rock Hunters*. Social aspects, variety and a sense of inquiry were the features that engaged members with the community, while time constraints, lack of interest and experience were the reasons that members dropped out. Technology and software usability had a crucial role in both cases. Furthermore, a comparison between the two communities indicated the importance of

illustrating inquiry activities as a part of a complete scientific process for supporting scientific literacy.

In this proposed orchestration of citizen inquiry communities, we combined our own belief in the importance of designing appropriate technologies to support inquiry learning with the needs of our participants. Although a readymade technology was adopted, both usability issues and the broader context of use were taken into account. A challenge to be overcome is how to design technology and social infrastructure that support scaling up. Technologies reported in the *implications for the design* section could aid scalability, for instance, by developing a better scaffolding system that automatically guides and informs members at every step of the inquiry process or a recommendation system that delivers to-do lists to individual members according to their interests.

Our aim with this study was to improve user experience and engagement, and support the inquiry learning aspect of citizen inquiry communities. Orchestrating principles from online communities, inquiry learning, design, and technology helped in creating an engaging space for community and inquiry learning. The findings of this research have added to the body of current research into how to engage members and support inquiry learning in online citizen inquiry communities with similar conditions. The next substantial step is to explore the efficiency of these design guidelines in further sustaining the communities and supporting inquiry learning.

References

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.

Andrews, D. (2002). Audience-specific online community design. *Communications of the ACM, 45*(4), 64–68.

Aristeidou, M., Scanlon, E., & Sharples, M. (2014a). Inquiring Rock Hunters. In C. Rensing, S. de Freitas, T. Ley & P. J. Muñoz-Merino (Eds.), O*pen 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. (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.

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.

Beuchot, A., & Bullen, M. (2005). Interaction and interpersonality in online discussion forums. *Distance Education, 26*(1), 67–87. doi:10.1080/01587910500081285

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

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

Brown, R. (2001). The process of community-building in distance learning classes. *Journal of Asynchronous Learning Networks 5*(2), 18–35.

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

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

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

Crall, A. W., Jordan, R., Holfelder, K., Newman, G. J., Graham, J., & Waller, D. M. (2013). 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

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

Design-Based Research Collective. (2003). Design-Based Research: An Emerging Paradigm for Educational Inquiry. *Educational Researcher*, *32*(1), 5–8.

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

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

Fischer, G. (2011a). Understanding, fostering, and supporting cultures of participation. *Interactions, 18*(3), 42–53. doi:10.1145/1962438.1962450

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

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

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 September 21, 2016, from http://www.flossproject.org/papers/ghosh-2005.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

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 September 21, 2016, from http://oro.open.ac.uk/42030/1/EARLIsig20meeting_submission_3_final %281%29.pdf

Iriberri, 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

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 September 21, 2016, 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 September 21, 2016, from http://discovery.ucl.ac.uk/1395531/

Kensing, F., & Bloomberg, J. (1998). Participatory design: Issues and concerns. *Computer Supported Cooperative Work, 7*(3–4), 167–185.

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).

Kubey, R., & Csikszentmihalyi, M. (2013). *Television and the Quality of Life: How Viewing Shapes Everyday Experience*. New York, NY: Routledge.

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

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

Lo, W., Delen, I., Kuhn, A., McGee, S., Duck, J., & Quintana, C. (2013*). Zydeco: A mobile-based learning system to support science inquiry learning.* Paper presented at the 2013 Annual Meeting of the American Educational Research Association.

Maher, M. L., Preece, J., Yeh, T., Boston, C., Grace, K., Pasupuleti, A., & Stangl, A. (2014). NatureNet: A model for crowdsourcing the design of citizen science systems. In *Proceedings of the 2014 CSCW Companion* (pp. 201–204).

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

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

Nielsen, J. (2006, October 9). Participation Inequality: The 90-9-1 Rule for Social Features [Web log post]. Retrieved September 21, 2016, from http://www.nngroup.com/articles/participation-inequality/

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

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., & 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

Preece, J. (2000). *Online Communities: Designing Usability and Supporting Socialbilty.* New York, NY: John Wiley & Sons, Inc.

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. (2016). Citizen Science: New Research Challenges for Human–Computer Interaction. *International Journal of Human-Computer Interaction*, *32*(8), 585–612. doi:10.1080/10447318.2016.1194153

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.

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.

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.

Schuler, D., & Namioka, A. (Eds.). (1993). *Participatory Design: Principles and Practices.* Hillsdale, NJ: Lawrence Erlbaum Associates.

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.

Sharples, M., Jeffery, N., du Boulay, J. B. H., Teather, D., Teather, B., & Du Boulay, G. H. (2002). Socio-cognitive engineering: a methodology for the design of human-centred technology. *European Journal of Operational Research*, *136*(2), 310-323. doi:10.1016/S0377-2217(01)00118-7

Sharples, M., Scanlon, E., Ainsworth, S., Anastopoulou, S., Collins, T.,Crook, ., Jones, A., Kerawalla, L., Littleton, K., Mulholland, P., & O'Malley, C. (2015). Personal inquiry: orchestrating science investigations within and beyond the classroom. *Journal of the Learning Sciences*, 24(2) pp. 308–341

Silvertown, J., Harvey, M., Greenwood, R., Dodd, M., Rosewell, J., Rebelo, T., Ansine, J., & McConway, K. (2015). Crowdsourcing the identification of organisms: A case-study of iSpot. *ZooKeys*, *480*, 125. doi: 10.3897/zookeys.480.8803

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

Steen, M. (2011). Tensions in human-centred design. *CoDesign*, *7*(1), 45-60. doi:10.1080/15710882.2011.563314

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).

Suriowecki, J. (2005). The Wisdom of Crowds: Why the Many Are Smarter Than the Few. *Business Economics*, *41*(4), 63–65.

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

Wenger, E., McDermott, R. A., & Snyder, W. (2002). *Cultivating Communities of Practice: A Guide to Managing Knowledge*. Harvard Business School Press.

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