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Chapter 13

Smart Activation of Citizens: Opportunities and Challenges for Scientific Research

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ABSTRACT

This chapter focuses on how, by "activating" the citizen's engagement in the research process, the scientific community has a smart way to benefit from the wisdom of the "crowd". There are countless success stories in which citizens participate, contributing with their knowledge, cognitive capacity, creativity, opinion, and skills. However, for many scientists, the lack of familiarity with the particular nature of citizen participation, which is usually anonymous and volatile, turns into a barrier for its adoption. This chapter presents a problem-based typology for citizen-science projects that aims to help scientists to choose the best strategy for engaging and counting on citizen participation based on the scientific problem at hand; and some examples are included. Moreover, the chapter discusses the main challenges for researchers who intend to start involving the citizens in order to solve their specific scientific needs.

INTRODUCTION

Historically, scientific research has been based on integrity, objectivity, truth-seeking and autonomy. This autonomy has led to the creation of a boundary between academia and society, thus dictating that science should be conducted only by scientists and acknowledged by their peers, for the benefit of society. However, new technologies and the popularity of Internet have led to the establishment of a new collaboration paradigm. The combination of crowdsourcing together with the advancement of mobile technologies opens up huge potential benefits for science, society, and the environment.

One of the greatest challenges of modern science is to transform the former border between academia and society into a place where ideas and interests can encounter and collide. Citizen science transforms this border into a permeable boundary that allows the union and exchange of different knowledge, skills and interests with benefits for all participants: scientists, citizens, and partners.

Although there are numerous citizen science projects in various parts of the world, only few studies have addressed the specific managerial aspects of citizen engagement in scientific domain and the dimensions that should be evaluated before and during its adoption. A better understanding of these aspects and related mechanisms can provide the "perfect experience" for the citizen scientist. To attract and retain citizens willing to collaborate with science, assure the quality of the contributions and the attendance to standards, and support a large number of contributors and contributions, are some of the challenges faced by managers of citizen science projects.

This chapter will present an overview of different opportunities for smart collaboration between citizens and scientists. It presents a problem-based typology in order to explore some representative examples of citizen science projects. Additionally, different types of projects will be grouped according to a pushed or pulled data approach adopted by the scientist. A smart activation decision tree is proposed in order to: help project managers assess which types of problems they need to solve, identify if the particular scientific objective of the project is compatible with the use of citizen science, and select which category of solution is best suited to the problem. An assessment of the main challenges for the design and management of these projects, as well as the challenges related to motivational aspects and quality control, will be presented. We believe this chapter will serve as a guide for scientists to advance towards this new paradigm and achieve the benefits associated with the smart activation of citizens in modern science.

BACKGROUND

In the new age of modern science, which is increasingly global, interconnected, and involves more international collaboration ("The Royal Society", 2011), citizen science has emerged as a form of crowdsourcing in which geographically distributed members of the crowd are invited to collaborate with scientists by applying some human cognitive ability on a large scale. This new paradigm has been studied by many authors, including Haklay (2013, 2014), Wiggins & Crowston (2010, 2012), Dickinson et al. (2010), Nov et al. (2010), Alabri & Hunter (2010), and Bonney et al. (2009) to name just a few. In accordance to this paradigm, members of the general public are promoted to the role of citizen scientists, in the stages of real scientific research and, therefore, collaborating to the creation of scientific knowledge.

New scientific methods are being created with the support of the Internet and mobile technology, thus allowing scientists to expand their network of collaborators beyond the limits of institutions. Ubiquitous and pervasive technology has broken the barriers of time and space, allowing a greater and more diverse number of collaborators to be engaged in scientific activities. The use of crowdsourcing platforms is making possible the participation of large groups to perform tasks that were once confined to small groups of experts. Recent innovations in information, communication, and technology — from smartphone apps to real-time crowdsourcing — are undoubtedly making citizen engagement far easier than ever before in history.

Currently, crowdsourcing is considered to be an umbrella or generic term, since it embraces a variety of approaches that exploit the labor force and cognitive potential of a large and open crowd of people (Geiger, 2011a). Crowdsourcing for science can be characterized either by an *open call* — which is also described as "self-identification of contributors" and allows anyone, who is interested and capable, to participate (Howe, 2009) — or a *restricted call* (pre-selection of contributors), which is concerned with restrictions regarding the group of potential contributors (Geiger et al., 2011a). In the second case, the interested participant must possess certain qualifications (e.g., specific skills or knowledge) or represent a specific context or ethnography, such as geographic distribution, social class or education, age, and gender, among others.

Citizen science projects go beyond the simple use of a citizen workforce. They promote opportunities for entertainment, education, and quality of life improvements, since many projects focus on local issues related to the everyday life of the citizens. Involving citizens in authentic research provides participants with valuable experience and the opportunity to make significant contributions to scientific research. Furthermore, it can promote behavioral change and increased environmental awareness, if also designed to educate citizens through their participation (Dickinson et al., 2012; Newman et al., 2012 & Bonney et al., 2009). On the other hand, for the scientist, citizen participation adds value to the scientific process bridging the gap between science and society (Pfeffer & Wagenet, 2007). The involvement of partners — such as civil society organizations, local associations, scholar networks and non-governmental organizations — is common in citizen science.

What distinguishes collaborative projects with citizen participation from the conventional mode of collaboration in scientific research is precisely the lack of a formal agreement and commitment to work, which leads to more flexibility in performing the tasks. For Haklay et al. (2014), this can be a challenge to professional scientists who are used to working only with their peers, in a top-down manner.

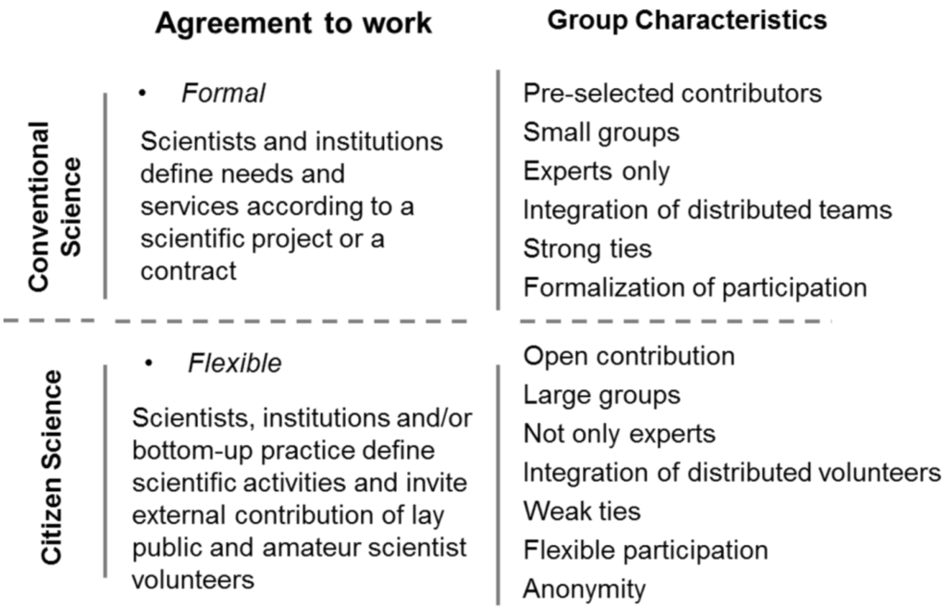

Figure 1. Main differences between conventional scientific projects and citizen science projects

Citizen science projects require "hybrid" management that allows a balance between leadership rigidity, hierarchical organizational structures, and formal working relationships, as opposed to the engagement flexibility of the amateur scientist; that is, a contributor without a formal working relationship who has different motivations (entertainment, altruism, seeking new skills and knowledge, etc.). Therefore, a tailored management approach is required to increase the chances that both contributors and scientists achieve their expectations and goals (Uchoa et al., 2013).

Despite the knowledge acquired with many successful citizen science projects, the integration of such projects with more conventional scientific research activities is still challenging. It involves culture changes in research institutions and more rigorous control of data quality. Ensuring reliable inputs by citizens depends on the good design of the task to be performed by the citizen, which includes the choice of technology and best management strategy for mobilization, participation, and communication, as well as the definition of quality control methods, which must be taken into account from the beginning of the project design up until the final stage of validation and approval of the contribution.

Citizen science projects previously conducted in local communities and in teaching initiatives, now benefit from: the infrastructure of the Web; the popularity of mobile device usage; and a large number of potential contributors connected to the Internet, who are ready to be activated on scientific projects of common interest.

CITIZEN SCIENCE OPPORTUNITIES

The opportunities for citizens to participate and help solve real-world scientific problems grow every day. These opportunities can be grouped into two broad categories, according to a pushed or pulled data approach adopted by the scientist. These two approaches in citizen science describe the exchange of data or information between citizens and scientists. It should be guided by the scientists' needs for new data and information, or due to the demand of massive data analysis or processing, depending on the **scientists' points of view**.

1. **Pushed approach (data analyses)**: Scientists ask citizens to collaborate with science through classifying and analyzing large datasets that neither computer nor individuals alone can deal

with. Scientists "push" the data toward citizens in order to use their collective or individual cognitive capacity.

2. **Pulled approach (data collection)**: It is based on scientific demand for new data or information, and is especially used for surveys, investigations, and monitoring. For instance, when demand is higher than the scientists' ability to collect data from the physical environment, the scientists "pull" the data they need from citizens and ask them to collaborate with their capacity to observe and collect environmental data.

The pushed data approach should be used in projects that require the analysis and classification of large volumes of digital data obtained automatically and continuously by sensors, telescopes, and other electronic devices. Digitalizing information of old analog data collections such as the weather observations of ship's logs or herbarium specimens are also part of this approach. These type of citizen science projects were labeled as "virtual" by Wiggins & Crowston (2011) and "volunteer thinking" by Ponciano et al. (2014). These projects aim to gather citizen scientists, who can contribute by executing human computation tasks. Participants collaborate via the Internet through games or tools that assist scientists in solving important scientific problems such as: recognizing patterns in images, sounds, and videos; text transcription; and geocoding, among other activities which also include scientific discovery outcomes. Contributors follow a sequence of activities, predefined by scientists dealing with a scientific computational problem.

This approach takes advantage of distributed human computation, which is described by Quinn & Bederson (2009) as a kind of task used to resolve problems that cannot be solved just by computers or just by humans, but for which a solution can be reached if both work together.

On the other hand, the pulled approach is usually associated with the collection of large amounts of data across large areas and/or for long periods of time. These collection tasks are usually performed outdoors and the data obtained are shared with projects in the form of text, images, sounds, and/or videos. This approach, which is also referred to as "citizens as sensors", has been widely discussed by Burke et al. (2006) and Goodchild (2007). Most citizen science projects belong to this category and there are many different examples in the literature: Conservation and Investigation (Wiggins & Crowston, 2011), Volunteer Monitoring (EPA, 2012), Volunteered Geographic Information (Goodchild, 2007; Haklay et al. 2013), and Volunteer Sensing and Participatory Sensing (Cuff, 2008; Estrin, 2010). Also belonging to this category are projects — generally related to the areas of psychology and medicine — aimed at collecting personal information.

There is also a third approach that does not fit properly in neither of the two data oriented categories above:

3. **Ideation approach**: includes those projects that use the citizen participation for the generation of new ideas or for the solution of complex problems. The main issue of these projects is not exactly weather to use the pulling or pushing of data, but rather to develop entirely novel ideas with the direct help of the citizen.

These three approaches were used to create a decision tree for the smart activation of citizens, in order to help scientists determine which type of approach is most useful for each specific scientific problem. Figure 2 illustrates these logical steps.

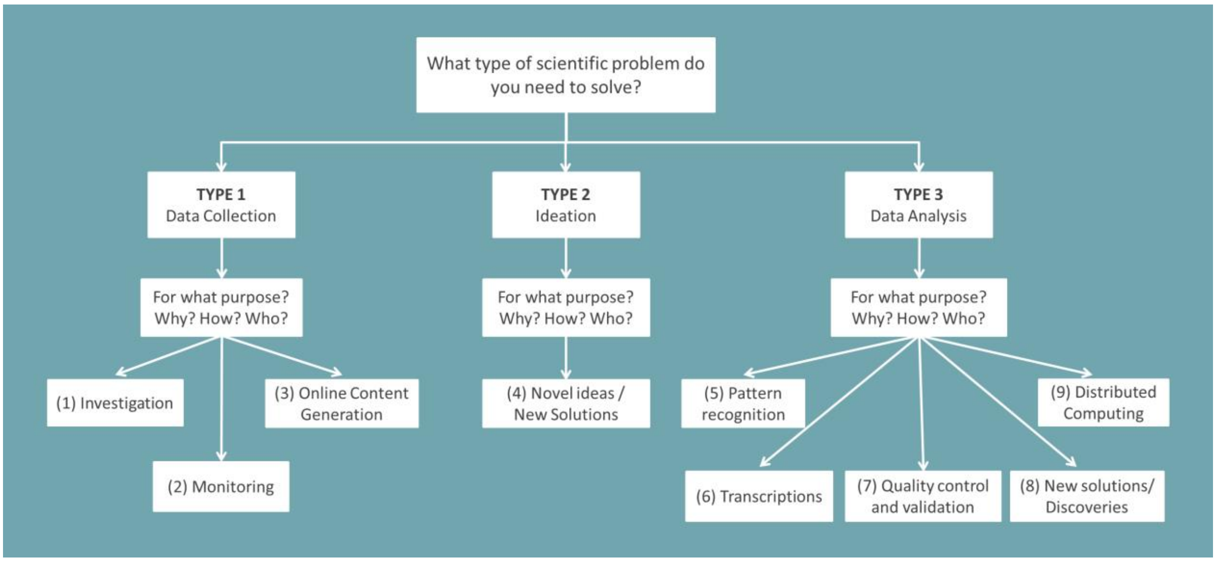

Figure 2. Decision tree for the smart activation of citizens

First, the scientist needs to determine whether the type of scientific challenge is a data management problem; that is, whether it involves: (1) management of data collection (pushed data approach); (2) analyzing existing data (pulled data approach); or (3) an ideation problem.

After this decision, the next question to answer is: What is the purpose of the citizen collaboration? Understanding the purpose and the "why" and "how" of the external contributions can accelerate the conventional science is a first step towards deciding whether or not to engage citizen participation.

Depending on the type of problem, a specific target public must be defined and mobilized. The profile of "who" will be activated correlates strongly with the characteristics of the scientific activities to be delegated to the participants. The precise identification of the skill set, abilities, knowledge, and individual characteristics of potential participants is as important as the design of appropriate task.

Like any other scientific research, before starting a project, the scientist needs to clearly define the problem and the corresponding solution. Defining the problem to be investigated and the question to be answered will help in describing the tasks and defining what type of scientific contribution the citizen can make to the project.

It is also important to discover and evaluate what others have done in similar projects. This helps verify the need to start a new project or to extend an existing one.

The most common opportunities for activating citizen participation in scientific research were grouped into 9 different categories. These citizen science categories are not exclusive, and in some projects they are combined to enhance the qualities of each other. Depending on the strategic management approach and the question to be solved, the best category of task to be given to the citizen scientists may be one of the following:

Category 1: Investigation or surveillance

Most scientific opportunities for engaging citizens with science belong to this category. The projects are particularly focused on ecology, environmental sciences, and related fields that require data collection from the physical environment (Wiggins & Crowston, 2011; McKinley et al., 2015), and they depend on the geographic location and the volunteer's use of mobile devices to contribute with data and observations. According to Nichols and Williams, (2006), in this category of project, scientists are not guided by a priori hypotheses and their corresponding models. For example, in research areas such as ornithology (eBird) and marine biology (JellyWatch), the citizen scientist contributes with the sighting and collecting of data on birds, and jellyfish and other marine organisms (e.g., man-of-war, squid, mammals and algal blooms), respectively. The citizen scientist follows standardized data collection protocols to increase the amount of data, in time and space, for one or more biological or physical parameter. These data are used for various purposes, and combining data analysis with other information allows scientists to discover new patterns and trends.

On the other hand, scientific research can benefit from crowdsourcing as a means of obtaining personal information. For instance, the Animal Ownership Interaction Study, which was recently launched by the Center for Canine Behavior Studies, recruits citizen scientists to fill out an online form and take part in surveys collaborating with science. The main objective of this research is to understand how owner personality affects pet behavior.

These projects require large amounts of data and, in general, participants do not need to have expertise to contribute. Often, participants join the project due to having a personal interest in the project's theme or because they already perform the activity as a hobby. For Bonney and Dickinson (2012), what motivates citizen scientists is a strong interest in the organisms being studied, a curiosity about the world around them, and a desire to advance the field of science. The benefits obtained by the managers of this category of project are: increased amount of data collected, expansion of geographic coverage of the surveyed area, increased period of collection, dissemination of knowledge, and increased participant awareness in relation to their environment (Tweddle et al., 2012) and health issues.

Category 2: Monitoring

Many scientific research institutions are developing "volunteer monitoring" programs, which involve volunteers, members of the general public, and a wide range of community groups in collecting and reporting personal or environmental data.

Projects in this category, according to Nichols & Williams (2006) are designed and implemented based on a priori hypotheses and associated models of system responses to management.

This type of smart activation helps in: bridging the gap between science and society, reinforcing public confidence in science, and allowing direct involvement of the general public in the generation of data. As a result, decision-making may become more democratic (Pfeffer & Wagenet, 2007), thus giving it clear relevance in education and policy.

Projects of this category are aimed at the management and monitoring of public health and natural resources, and they can be classified into two sub-categories: (1) ongoing data collection for scientific investigation or environmental conservation; and (2) immediate data collection for monitoring and decision-making on epidemics or catastrophic events.

1) Long term scientific investigation

This sub-category of projects seek to educate citizens on important issues related to science and to the environment, by contributing to projects involving water and air quality monitoring, global warming, biodiversity, global health, and many other scientific opportunities.

For instance, CoralWatch is a citizen science project managed by the University of Queensland, which aims to improve the extent of information on coral bleaching events and coral bleaching trends (Reid et al., 2009).

The BudBurst project draws on the voluntary cooperation of citizens to help scientists understand climate change by making regular observations of the occurrence and phenology (red, flowering, fruiting, and leaf loss) of various plant species. Participation was designed to be performed in six steps: (1) Register for an account; (2) Choose a plant; (3) Download Datasheet; (4) Locate/Describe site; (5) Make observations; (6) Report observations online.

Volunteer contributors can choose the plants they want to observe from a decision tree. Five groups of plants are available at the project website: wild flowers and herbs (110); deciduous trees and shrubs (105); evergreen trees & shrubs (39); grasses (18); and conifers trees (10). These groups and their respective species were selected because they are easy to identify and they occur widely in the United States. For each of the five groups there is educational material explaining the phenophases.

The citizen scientist can also contribute to science by providing personal information that helps scientists monitor public health. For instance, the Flu Survey project[1] aims to collect personal information about flu-like symptoms experienced during the winter months. These data have been used by researchers at the London School of Hygiene and Tropical Medicine and also in United Kingdom's Tropical Medicine and Public Health (NHS) since 2009 to monitor influenza trends in the UK. The data provided by citizens are analyzed and displayed on a Web map updated every three minutes. Currently, more than 6,000 citizens, from all over the UK, have contributed to this project.

2) Crisis, Emergency, and Disaster Monitoring

The goal of these projects is to allow citizens to report relevant information during disasters or emergencies. This information is relevant to many scientific research areas such as biology, seismology, climatology, geology, and public health, among others.

According to Okolloh (2009), "Information in a crisis is a patchwork of sources. You can only hope to build up a full picture by having as many sources as possible" (p.66). The Ushahidi[2] platform was built to gather geolocation data reported by large groups of volunteers and to facilitate the sharing of information through visualization and interactive mapping. Scientists can use these data to monitor and understand catastrophic events, such as the magnitude 7.0 earthquake in Haiti on January 12, 2010. With the same goal, the "Did You Feel It?" (DYFI)[3] of the U.S. Geological Survey harnesses the potential benefits of citizen science for monitoring earthquake events.

The growing use of smartphones, which are increasingly accessible, and the pervasive connectivity and consolidated data in monitoring and surveillance projects are working together to create a public that can objectively record, analyze, and discover a variety of patterns that are both important in their lives and also contribute to scientific research. In the literature, new terms like volunteered geographic information (VGI) and participatory sensing have come to describe this new potential for participation. These two new terms, which are not mutually exclusive, are described below (both are applied to the categories 1 and 2 discussed above).

Volunteered Geographic Information (VGI)

First defined by Goodchild (2007), VGI "has the potential to be a significant source of a geographers' understanding of the surface of the Earth".

Since the vast majority of citizen science is geographic, that is, it requires a location on the Earth, the overlapping of citizen science with VGI can be seen as a way of updating geographical databases (Goodchild 2007; Haklay et al., 2013). Notwithstanding, the opportunities of using VGI for science go beyond collection and database storage. VGI enhances the collective creation of georeferenced dynamic maps. There are huge opportunities for citizen science to build collaborative maps for various objectives and interests, as described above.

Maps are not static, because information is added and it changes over time and space. The citizen's data collection activities can be valuable for scientists, because these activities enable the generation of a greater volume of data, as well as increasing the accuracy and quality of information.

Participatory Sensing

For Estrin (2010), participatory sensing is the process by which individuals and communities are increasingly using mobile devices and cloud services to collect and analyze data systematically for several purposes.

The use of humans as a network of sensors is an approach that has already been discussed in the literature and it has been employed in various citizen science projects for data collection (Burke et al., 2006; Goodchild, 2007).

A new collective capacity is emerging through the use of sensors built into mobile phones and connected to web services (e.g., cameras, motion sensors, and GPS). For Goldman et al. (2009) participatory sensing allows people to participate in activities in which they can detect and analyze aspects of their lives that were previously invisible. An example of the discovery of this invisible aspect is the Noise Tube project.

NoiseTube is a research project started in 2008 at the Sony Computer Science Lab in Paris, which is currently maintained by the Software Languages Lab at the Vrije Universiteit in Brussels. The main goal of this project is to enable citizen scientists to measure the personal exposure to noise resulting from using mobile phones. The geolocation and the measurement results are shared online in collective noise mapping of cities (Maisonneuve, 2009).

Category 3: Online content generation

Projects classified as category 3 aim at creating collective online content. In many cases, citizen collaboration are often supported by Wiki technology. Like other citizen science activities, it is only necessary to register a username and password to join the online community of citizen scientists. Effective community participation is what guarantees the content and the quality of the data. Included in this category are the Wikiflora, WikiAves and Polimathy projects, just to name a few.

The WikiAves project[4] is a Brazilian citizen science project that is one of the largest repositories on the distribution and abundance of birds. Unlike other projects that request a species list of birds to be filled in, WikiAves only requests that citizens send an image or sound record, as well as a description and location of the bird sighting. Known as the "Facebook for birds", it currently has 1,858 pages — one for each Brazilian species — and all pages contain relevant information published collaboratively by volunteers. This number of pages is almost equivalent to the total of 1,901 species known and registered on the official list of the Brazilian Ornithological Records Committee. Up until March, 2016, the total number of participants was of 23,558. The number of records included 1,578,557 images and 93,365 sound records.

Category 4: Ideation — Creating novel ideas and new solutions

Such projects promote great challenges and competitions involving issues related to scientific research. The coordinators of this category of projects can create their own platforms or use marketplace platforms designed exclusively to manage the tasks. InnoCentive, Climate Collab, and Citizen Sky are examples of this type of opportunity, which brings citizens together to collectively create novel ideas and solutions.

Today's scientific projects are no longer restricted by the ability and skills of professional teams. They can now appeal to open and varied audiences, thus allowing different skills, knowledge, and interests to be added to projects. Climate Collab[5], for example, is a research project of the Massachusetts Institute of Technology, and its goal is to harness the collective intelligence of thousands of people worldwide to address global climate change. The participant can create and submit proposals for what should be done about climate change, or collaborate with people worldwide to outline ideas that will help reduce climate change impacts on the planet.

Open competitions discuss topics in different areas of knowledge such as low-carbon energy, building efficiency, energy supply, land use, and waste management, among many other topics.

Category 5: Pattern recognition

The increasing scientific need for analyzing and processing large datasets, which neither small groups of scientists nor computers can solve alone, opens up a variety of opportunities for citizen collaboration in web-based citizen science projects. Generally, the tasks to be performed require some type of pattern recognition, which can only be performed by the human brain.

Pattern recognition is used to classify massive online datasets of images, sounds, or videos. Citizens participate by following protocols with standards and guidelines previously set by scientists. Activities are executed exclusively online, and results have proven that the quality of such activities is similar to that produced by professional scientists (Canfield, Jr. et al., 2002; McKinley et al., 2015). One of the most successful examples is the Galaxy Zoo project, which is a citizen science project on astronomy (Lintott et al., 2008). Planet Hunters[6] is a similar project that features a quick and easy-to-assimilate tutorial that gives credits for the volunteer work performed. The tutorial is always available at any stage of task execution. The task is simple, and in a few steps the collaborator can finish the classification of an image.

Some projects stimulate task completion through games and competition. For instance, “Citizen Sort” is a platform where there are many games to help scientists with classification tasks about species of insects, animals and plants. One of these games is “Happy Match” a taxonomic classification game, in which the taxonomic titles vary according to the pictures that must be classified. The game design includes a question, pictures that must be classified, and pictures that represent the possible classifications. Thus, the collaborators must compare the images that need classification with the classification options. From the images that must be classified, at least two of them have already been classified by experts and they are used to compute a collaborator’s accuracy (score). The scores are used by Citizen Sort to maintain a ranking of the collaborators, who are invited to perform more tasks (or play more games) and enhance their position in the ranking (Crowston & Prestopnik, 2013).

Category 6: Document transcription

Like the previous category, the science community makes use of distributed human computation to benefit from the cognitive ability of millions of minds connected to the Internet to perform simple tasks related to digital document transcription.

These projects are aimed at completing tasks that are easily performed by humans but which computers alone cannot yet perform. Tasks that are part of such projects are simple and do not require specific skills. Digitalizing information of old analog data collections such as the weather observations of a ship's log - Old Weather project (Eveleigh et al., 2013) or herbarium specimens - herbaria@home projects (Groom et al., 2014) are examples of this approach.

Category 7: Quality control and data validation

Citizens participate in these projects by helping to improve data quality. In the RiverWatch project, participants try to identify out-of-range observations. They copy their observations into a worksheet, sort them by ascending or descending numerical attributes, and then compare observations with each other. After this, it is possible to identify duplicated observations or out-of-range values that were mistyped and must be corrected or removed (Sheppard & Terveen, 2011).

Hutt et al. (2013) investigated the best task design for obtaining annotations for microscopic images, in order to determine how clumpy an image is. Three task designs were proposed: classification, scoring, and ranking. In classification tasks, collaborators must classify an image as either clumpy or not clumpy by clicking on the corresponding button. The scoring tasks ask collaborators to give a score for an image. Finally, the ranking tasks show three images for collaborators, who are required to order them from the least clumpy to the clumpiest, in which the least clumpy image must appear to the left and the clumpiest image to the right.

Category 8: New Solutions/Discoveries

This type of opportunity is related to scientific problems that require large-scale human-computer interaction for solving unpredictable problems. Typical examples of success cases include the Foldit and EteRNA projects. These projects use GWAP, human computing, crowdsourcing, and social computing in order to attract common citizens to perform scientific tasks. Such projects seek to encourage the participation of people who have an interest in science, but who are also looking for entertainment and leisure.

Foldit was developed by the Center for Game Science at University of Washington (UW) in collaboration with that university’s Department of Biochemistry. It is a crowdsourcing computer game that enables citizens to contribute to solving protein-folding problems (Cooper et al., 2010). Moreover, it is a multiplayer online game that uses the knowledge and intuition of non-specialists to solve protein-folding problems by using a host and tools provided. Since its release, Foldit has gained over

100,000 players. The best Foldit players have little to no prior exposure to biochemistry (http://fold.it/).

“Foldit showed that it is possible to effectively ‘crowdsource’ human problem solving in order to solve very hard scientific problems, and that the gaming environment is capable of turning novices into highly skilled researchers. The goal of the Center for Game Science[7] is to generalize and expand the success of Foldit to a wider range of problems in science, education, and beyond.

Category 9: Distributed computing

In this category of project, the scientific result does not depend on direct human activity, but rather on the computational processing of the machine provided by the volunteer. This type of project has been classified as citizen science, despite there being no human-computer interaction in this activity. Nevertheless, volunteer computation is helping scientists to save time and also speed up the processing of scientific information through distributed computation. These are projects aimed at using the idle time of participants’ computers to process scientific research data. Volunteers contribute by simply "lending" their computers, without doing any additional activity. The computer network formed by collaborators produces a huge network of distributed computing, which is a way of overcoming the technological limitations a project may face. These projects typically use the idle time of computers connected to the internet to: find extraterrestrial intelligence (SETI@Home), study samples of solid matter collected outside the solar system (Stardust@home), or help determine three-dimensional shapes of proteins (Rosetta@Home).

Every day, new forms of citizen participation in scientific research arise and, consequently, the volume of data that are generated, processed, or recombined is increasing. There are numerous current possibilities for the use of this data in the present, and huge potential for its use in the future. Therefore, more and more data are being stored, even if it does not have value today. After all, besides preserving raw data, what really matters for scientists and decision makers is the added value; that is, the ability to recombine and transform raw data into useful information that is available and easily accessible.

Grouping citizen science projects is a difficult task, due to the wide variety of potential opportunities in scientific research. However, if we consider that what binds the scientist to the citizen are the data and/or the knowledge to be acquired or transmitted, grouping these projects into a pushed or pulled data approach seems appropriate and cohesive with the new era of data-intensive scientific discovery.

CITIZEN SCIENCE CHALLENGES

Citizen science refers to contexts in which most individuals are not part of the academic community, so they engage in scientific projects, waiting or not for a reward for their effort (Tweddle et al., 2012). The use of amateurs, as opposed to scientists, can reduce confidence in the results if the task has not been designed to prevent or minimize errors. Well-defined criteria should be developed at the design stage and accompanied during the performance of the task and the delivery of the contribution. Motivation, quality control, and management of a large number of contributors and contributions are the main challenges faced by managers of citizen science projects. These three topics are discussed below.

Motivation

Often what motivates the citizen is the satisfaction of being part of a real research project, with the possibility for learning, leisure, activism, altruism, fun, recognition, as well as becoming acquainted with new people, places, and socio-environmental contexts.

If, on the one hand, citizen science enables data collection and analysis on a larger scale than the conventional method, on the other hand, it brings challenges associated with motivating individuals to engage in task performance.

The reasons associated with why citizens participate in scientific projects have been the focus of various scholars' research: (Wenger, 2002; Raddick et al., 2010b; Nov et al., 2011; Crowston & Prestopnik, 2011). Depending on the context of the project and the interest of the participant, the selection process may be triggered by one of the following factors: the research issues may arouse interest or they are already part of the person's day-to-day activities as a hobby; participants may have a vested interest in the outcome of the research and thus contribute to its goals; some projects make use of games and entertainment approaches, thus leading people to participate for leisure; or the reason for participation may be altruistic in nature.

Raddick et al. (2010) identifies four social groups as the main beneficiaries of successful citizen science projects: the volunteer contributors of the projects, the researchers behind projects, educators, and society. For the public, projects provide knowledge, entertainment, and experiences, which can ensure their motivation and lasting engagement. For researchers, they ensure that scientific activity, which cannot be solved in a short amount of time by a small team of professional scientists, will be executed quickly and cost-effectively within required quality standards. For educators, this kind of research helps them professionally by providing new opportunities for education. And for the affected communities, citizen science projects generate results and concrete benefits, which can bring scientific practice and society closer together. Thus, when designing experiments and products that will attract and retain the participants, the organization of citizen science projects should take into account the specific needs and concerns of the social groups that these projects interrelate with. In order for this to happen, identifying and knowing them seem to be essential requirements for the design of appropriate and effective projects.

Pant (2009) believes that a way for an organization to recognize potential participants is by paying attention to the way they act in the virtual communities in which they participate, including those that form around the research subjects of citizen science projects. Thus, social tools such as forums, blogs, wikis, microblogs, and chats — all of which are employed by Galaxy Zoo[8] and similar projects such as Foldit[9]— offer great potential for promoting the exchange of knowledge and experiences.

According to Nov (2007), it is important to understand the factors that lead people to freely share their time and knowledge with others, in order to increase the number of contributions and improve the user-generated content.

Wikipedia, the Web encyclopedia created by users, is a successful example of collaboration in the form of online content generation. The motivational factors of contributors appear to be critical for the maintenance of Wikipedia, as well as for other similar initiatives, since they depend on the contribution of volunteers who offer their time and talent without monetary reward. Therefore, in order to understand what is behind the contribution, it is necessary to understand what motivates participants and identify the motivations that are associated with high or low levels of contribution (Nov, 2007).

Several aspects of the project are directly related to the motivation of regular citizen to participate, including the complexity of the tasks delegated to them, and the importance they attach to their goals. Nov et al. (2011) conducted an experiment which aimed to study possible motivational factors in crowdsourcing systems. In this experiment, volunteer contributors formed two activities — the first was related to solving small parts of a large task and the second was related to image classification. Results showed that the motivational factors associated with the second activity were higher for all motivation indicators. Among the reasons influencing participants of the experiment, the major indicators were related to: the importance to be part of something collaborative; and due to intrinsic reasons such as altruism, entertainment, reciprocity, intellectual stimulus, and a sense of obligation to contribute.

Although compelled by a scientific need, citizen science is also able to meet the public's desire and provide them with many benefits, including knowledge, entertainment, and the opportunity to take part in scientifically authentic experiences. In the Galaxy Zoo project, for instance, this experience can be considered to be an authentic involvement with scientific practice, since the data analyzed, and the publications to which volunteers contribute, are exactly the same for professional scientists. Citizen science projects often provide the public with some form of education or development in their understanding of science (Wiggins & Crowston, 2010), and the resources used usually vary from texts, publications, sources of virtual content, and manuals, to online courses and interactive games that can be accessed on websites. These instructional resources provide benefits for both the participants and the projects themselves, because they simultaneously enrich the participatory experience of the volunteer contributors and improve the quality of their contribution.

However, the main motivator for effective engagement seems to be the pleasure associated with the participatory experience (Nov et al., 2011). For Wenger (2002), nothing replaces the vividness of participating as the main attraction for the engagement and retention of citizen scientists. The ability to generate interest, relevance, and value among participants, to the point of leading them to work in favor of scientific research is one of the main success factors in citizen science projects.

Data Quality

Data quality is one of the major concerns in scientific research. In particular, if the project is designed for collaboration with non-experts or amateurs, the chance of introducing errors may increase (Jordan et al., 2012). As a result, part of the scientific community considers data coming from citizen science projects to be unreliable to be used in conventional scientific research (Alabri & Hunter, 2010). However, the literature has shown that citizen science projects, when properly designed and conducted, can produce results as good as those produced by conventional science (Canfield, Jr. et al., 2002; McKinley et al., 2015), and also do it quickly and cost-effectively (Bowser & Shanley, 2013). Errors are expected, but collectively, the participation of nonprofessional scientists can generate knowledge and reliable results for scientific research (Soares, 2011).

Data quality is a key aspect in citizen science projects and requires further study. A study conducted in a project involving the mapping of invasive marine species revealed a high value placed on the accuracy of observations made by high school students. This study also found that the motivation had a positive impact on the completeness of the data set (Delaney et al., 2008).

Tweddle et al. (2012) emphasize the importance of training the participants to collect and analyze reliable data. Besides training, it is also important to provide user support, as well as create forms, handouts, field guides, or even a direct communication channel with the project team, in order to facilitate the participant's activity and minimize the complexity of the task.

The quality of data in monitoring programs should be evaluated from two perspectives: external and internal (Conrad & Hilchey, 2010). Nicholson et al. (2002) conducted a statistical comparison of environmental monitoring data collected by professionals and volunteers, and from this they concluded that the data quality is comparable to certain parameters.

Alabri & Hunter (2010) formulated a hypothesis that the use of trust and reputation metrics (as used to provide recommendation services in online social networks such as eBay and Netflix) can be applied to citizen science data. Trust models can provide simple and effective mechanisms for filtering unreliable data. Additionally, combining trust/reputation metrics with data validation services can significantly improve the quality and reliability of the data generated in the community, thus allowing its safe re-use by the scientific community. Among the various aspects evaluated to identify a set of criteria and attributes for measuring the confidence of the citizen science data, the authors suggested as criteria: the role and qualifications of the contributor (e.g., primary or secondary school student, doctoral student, volunteer, scientist, etc.); the quality and amount of data contributed; whether or not the contributor has had some kind of training; the frequency and the period of the contribution; and the classification of the contributor by other members (inferred or calculated). The authors developed a simple tag system in which members of the network can assign a degree of confidence to other contributors in the network. The added value of community confidence in a member of the network is calculated by considering both the direct trust value assigned by the network members and the indirect trust value which is inferred by additional attributes.

Antelio et al. (2013) proposed a collaborative framework named Qualitocracy to improve data quality in Citizen Science projects. By associating data quality dimensions to scientists through a voting network, the authors aimed to create a continuous process for data quality validation. Another project that employs experts' validation is FeederWatch Project – a citizen science program whose objective is monitoring the distribution and abundance of birds during winter. The system may require additional information or expert analysis regarding the data uploaded by participants. In this case, experts (project staff or regional biologists) may either accept observations or request additional information and photographic documentation from participants. When the extra information is uploaded by the participant, observations are either confirmed and accepted by the platform or non-confirmed and considered invalid and thereof discarded from data analysis (Bonter & Cooper, 2012). Thus, consulting experts permits to identify outliers that are mistakes or even rare observations, reducing the occurrence of errors in final data.

Management

Although there are different types of tasks, each project basically follows the same general structure: citizen scientists follow workflows and specific protocols, perform online tasks or collect data, and make observations of the real world that are later sent to the project's website via the Internet. The team behind the project validates, analyzes, and organizes the information sent by the contributor, and also publishes the results, not only in the scientific literature, but also in a variety of more accessible forums, ranging from websites, blogs, social networks, and wikis, to newsletters and emails. Participants are then able to see their contributions, compare them with the contributions of peers, and understand how their data help science.

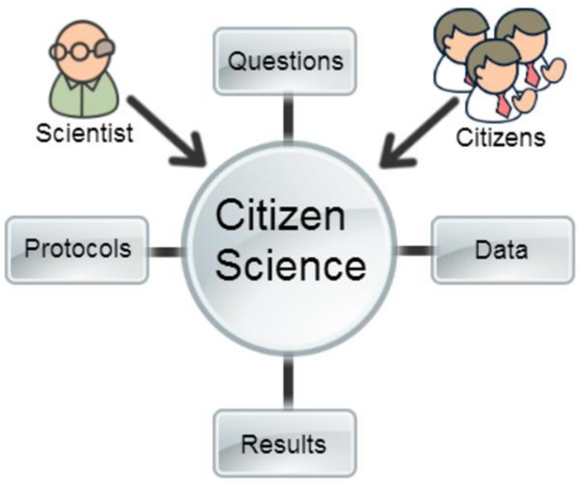

Figure 3. Generic model of citizen science projects

Nevertheless, although the execution of citizen science projects seems simple, the design and management of these projects is not a plug-and-play solution. Their implementation requires a tailored approach for each type of task in order to increase the chances that all involved parties meet their expectations and achieve their goals. Uchoa et al. (2013) proposed a conceptual framework known as Mix4Crowds to help citizen science enterprises conceive their crowdsourcing strategy and design their collaboration systems. It departs from the basic principles of traditional marketing models and incorporates the specific requirements of citizen science projects, structured according to a four-stage process, with each stage aimed at gathering, analyzing, and defining the most relevant features, criteria, and requirements related to one of the following four dimensions: crowds, collaboration, communication, and platform. The goal is to produce a coherent, integrated, and balanced mix of features and requirements through the identification and weighting of the design aspects related to each of these four dimensions.

Marketing strategies are widely used by business organizations to develop their relationships with their public. When choosing the appropriate dimensions for developing its marketing mix, an organization usually adopts a predominant producer- or consumer-oriented perspective, each of which will have its benefits, shortcomings, and challenges. For example, product and service features, price policies, promotion, and distribution are the four most common dimensions used by traditional consumer goods organizations when formulating their marketing mix, while consumer capacity, interests and needs, cost, convenience, and communication channels are consumer-oriented dimensions commonly adopted by service organizations. The Mix4Crowds framework resembles the traditional marketing mix model with its four dimensions; however, its approach adopts neither a pure producer nor a pure consumer perspective. Along with the adjustment of the four dimensions, the scientist should also consider the needs and requisites of the three main groups involved: managers (or the team behind the project), volunteer contributors, and institutional partners. For this reason, in order to choose the most appropriate design, it is important to take into consideration the volunteer contributor's point of view — both as producer (e.g., collecting data or transcribing documents) and consumer — about what the project has to offer. In citizen science projects, participants have different motivations, which end up generating additional challenges for researchers who wish to make use of this new collaboration paradigm.

In citizen science projects, each volunteer contributor has a twofold role. When participants begin contributing to a project, they become part of the research team, adding skills and expertise, sharing with other participants and researchers the same goals, methods, and protocols. Nevertheless, each participant is also a consumer of the benefits that the project has to offer, which include: knowledge, experience, social interaction, acknowledgment, entertainment, and leisure. Participants and projects become linked in a way that resembles a provider-consumer or "prosumer" relationship. Prosumers, as they are known in the marketing area, need their own strategy so that their membership is acknowledged and their connection with the project preserved.

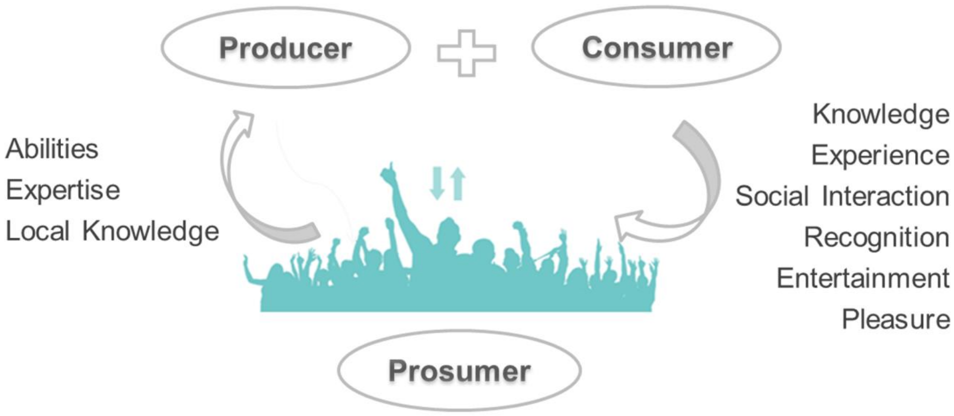

Figure 4. Twofold role of volunteer contributors in citizen science projects.

Add to this the fact that citizen science projects depend on the ability to attract and retain volunteer contributors, usually by creating the perception of value and relevance in many levels among participants. Nov et al. (2007, 2011), describe the importance of delivering a "participatory experience" through something that has the power to attract new members and motivate their lasting and productive collaboration.

Additionally, citizen science projects have characteristics that differ from conventional scientific projects used for managing and motivating employees in an organization, in which there are rigid deadlines to suit more formal and hierarchical environments. In citizen science projects, scientists need to make management more flexible due to the fluidity of participation, which is sometimes anonymous and volatile. Different to what happens in conventional scientific collaboration projects, citizen science projects do not spontaneously organize as a result of the interaction of their participants (Preece, 2002). In citizen science, the results depend much more on the individual participation of volunteer contributors than on their mutual interaction, and this participation is subject to the supervision of scientists or managers, as well as the hierarchical structures of command and power previously established (Wiggins & Crowston, 2012). These are structures that can be compared to those of business organizations (Wiggins & Crowston, 2010). After all, citizen science involves projects that do not rarely extend for long periods of time, and achieve large-scale participation and geographical distribution. This requires physical structures, materials, financial and human resources, communication efforts, and organized processes so that a continuous, durable, and reliable operation is guaranteed.

Just as with companies, citizen science projects must seek ways to increase the chances of achieving goals. For this to happen, it seems essential to have a form of organization and management that reconciles the rigidity of aims, timelines, and scientific methods with the flexibility and lack of formality appropriate for volunteer participation. Designing systems to support this type of scientific collaboration requires tailored organizational and task design to ensure scientifically valid results and sustainable contribution (Wiggins & Crowston, 2010; Uchoa et al., 2013). The authors believe that citizen science projects, especially those based on the web, can also benefit from the adoption of a marketing approach when designing their crowd engagement systems.

CONCLUSION

If, on the one hand, smart action to engage citizens with science brings benefits to modern research, by allowing collaboration on a larger scale than conventional methods and reducing time and cost, on the other hand, it brings challenges in terms of keeping citizens motivated and continuously engaged with the project.

Motivation, quality control, and management of a large number of volunteer contributors and contributions are the main challenges. It is important to bear in mind the citizen vision both as a producer (e.g., collecting and classifying data) and as a consumer of what the project has to offer. Often what motivates citizens is the pleasure of being part of a real scientific research project, the possibility of learning, combined with entertainment, as well as the opportunity of getting to know new people, places, and different social and environmental contexts. Thus, social tools, such as forums, blogs, wikis, microblogs and chats, offer great potential for promoting the exchange of knowledge and experience.

Citizen participation has been accelerated by the use of the Internet and new mobile technologies, and there are many successful cases. However, one of the main challenges of citizen science lies not in technology, but in management, quality control, and maintenance of the engagement and motivation of the participants. Constant campaigns, simplicity in user-interfaces, tutorials, acknowledgment, and feedback mechanisms including communication channels and publication of the results are the keys to success of such projects. It is important to provide support and a direct communication channels to ensure continuous feedback between project managers and volunteer contributors.

In order to make data reliable, it is important that the project assesses the needs and mechanisms for training participants to collect trusted data. The use of reliable and reputable metrics can provide simple and effective mechanisms for filtering unreliable data. The greater flexibility of participation, which is sometimes anonymous and volatile, requires the design of a strategy for management, communication, and the use of technology, in order to maximize quality, engagement, and maintenance of voluntary participation, but it also needs to generate benefits for all involved; that is, managers, volunteer contributors and institutional partners.

We believe the typology and concepts presented here can represent a guide to the opportunities and challenges for scientific research and inspire the creation of new initiatives for the smart activation of citizens.

KEY TERMS AND DEFINITIONS

Scientists: Leading or participating in the team behind the citizen science projects are primarily interested in the scientific outputs. They may be students, amateur scientists, professional scientists or research group coordinators.

Project: It is a citizen science activity. We use this term to incorporate the full range of citizen science including crowdsourcing, long-term monitoring and scientific investigations.

Participant: In general, is an unpaid person who takes part in a project by helping to define its scope, gathering or analyzing data and contributing with new ideas and solutions – a 'citizen scientist'.
Partner: An organization or group of people with a common interest relevant to a citizen science project (e.g. local communities, school groups, governmental agencies or Non-Governmental Organizations (NGOs); others scientific institutions, or members of a natural history group).
Smart Activation: An intelligent opportunity for scientists to activate the citizen's engagement in the steps of scientific process. The project management requires a tailored approach in order to increase the chances that both participants and scientists achieve their expectations and goals.

REFERENCES

Alabri, A. & Hunter, J. (2010). Enhancing the Quality and Trust of Citizen Science Data. In *Proceedings of 2010 IEEE Sixth International Conference on e-Science (e-Science)*, pp. 81-88.

Antelio, M., Esteves, M. G. P., Schneider, D. and Souza, J.M. (2012), Qualitocracy: A data quality collaborative framework applied to citizen science. In *Proceedings of the International Conference on Systems, Man and Cybernetics (IEEE SMC 2012).*

Bowser A. & Shanley, L. (2013). New Visions in Citizen Science. Washington, DC: Woodrow Wilson International Center for Scholars.

Bonney, R.; Cooper, C. B.; Dickinson, J.; Kelling, S.; Phillips, T.; Rosenberg, K. V. and Shirk, J. (2009). Citizen Science: A Developing Tool for Expanding Science Knowledge and Scientific Literacy. *BioScience*, 59 (11), pp. 977–984.

Bonney, R. I. C. K., & Dickinson, J. L. (2012). Overview of citizen science. Citizen Science: Public Participation in Environmental Research. *Cornell University Press*, New York, 19-26.

Bonter D. N. & Cooper C. B. (2012). Data validation in citizen science: a case study from Project FeederWatch. *Front. Ecol. Environ.*, 10 (6), pp. 305–307.

Burke, J. A., Estrin, D., Hansen, M., Parker, A., Ramanathan, N., Reddy, S. and Srivastava, M. B. (2006) Participatory sensing. *WSW'06 at SenSys '06,* Boulder, Colorado, USA.

Canfield Jr., D. E., Brown, C. D., Bachmann, R. W., & Hoyer, M. V. (2002). Volunteer lake monitoring: Testing the reliability of data collected by the Florida LAKEWATCH program. *Lake and Reservoir Management*. 18 (1), pp. 1–9.

Conrad C. and Hilchey K. (2010). A review of citizen science and community-based environmental monitoring: issues and opportunities. *Environmental Monitoring and Assessment, pp.* 1–19.

Cooper, S., Khatib, F., Treuille, A., Barbero, J., Lee, J., Beenen, M., Leaver-Fay, A., Baker, D., Popovi´c, Z., & Foldit players. (2010). Predicting protein structures with a multiplayer online game. *Nature* 466, 7307, pp. 756–760.

Crowston,K. & Prestopnik, N. R. (2011). Gaming for (Citizen) Science: Exploring Motivation and Data Quality in the Context of Crowdsourced Science through the Design and Evaluation of a Social-Computational System. In *IEEE Seventh International Conference on e-Science Workshops (eScienceW)*, pp. 28–33.

Crowston,K. & Prestopnik, N. R. (2013). Motivation and Data Quality in a Citizen Science Game: A Design Science Evaluation. In *46th Hawaii International Conference on System Sciences (HICSS),* pp. 450–459.

Cuff, B. D., Hansen, M. and Kang, J. (2008). Urban Sensing: Out of the Woods. *Communications of the ACM*. 51(3), pp. 1-33.

Delaney, D., Sperling, C., Adams, C., and Leun,g B. (2008). Marine invasive species: validation of citizen science and implications for national monitoring networks, *Biological Invasions*, 10, pp. 117-128.

Dickinson, J. L., Zuckerberg, B. and Bonter, D. N. (2010). Citizen Science as an Ecological Research Tool: Challenges and Benefits, *Annual Review of Ecology, Evolution, and Systematics.* 41 (1), pp. 149–172.

Dickinson, J. L., Shirk, J., Bonter, D., Bonney, R.,. Crain, R. L Martin, ,J., Phillips, T. and Purcell, K. (2012). "The current state of citizen science as a tool for ecological research and public engagement. *Frontiers in Ecology and the Environment*. 10 (6) pp. 291–297.

Estrin, D. (2010). Participatory sensing: applications and architecture. *IEEE Internet Computing*, 14 (1), pp. 12–42.

EPA - United States Environmental Protection Agency. (2012). Starting Out in Volunteer Monitoring. EPA 941-F002-004.

Eveleigh, A., Jennett, C., Lynn, S. and Cox, A. L. (2013). 'I Want to Be a Captain! I Want to Be a Captain!': Gamification in the Old Weather Citizen Science Project. In *Proceedings of the First International Conference on Gameful Design, Research, and Applications*, New York, NY, USA , pp. 79–82.

Geiger, D., Seedorf, S., Schulze, T., Nickerson, R. and Schader, M. (2011a). Managing the crowd: Towards a taxonomy of crowdsourcing processes. *Proceedings of the Seventeenth Americas Conference on Information Systems.* Detroit, Michigan, August 4-7, 2011, pp. I-II,

Geiger, D., Rosemann, M. & Fielt, E. Crowdsourcing Information Systems – (2011b). A Systems Theory Perspective, presented at the *22nd Australasian Conference on Information Systems*, Sydney.

Goldman, J., Shilton, K., Burke, J., Estrin, D., Hansen, M., Ramanathan, N., Reddy, S., Samanta, V., Srivastava, M. and West, R. (2009). Participatory Sensing: A citizen-powered approach to illuminating the patterns that shape our world, Foresight & Governance Project, *White Paper*.

Goodchild, M. F. (2007) Citizens as sensors: the world of volunteered geography, *GeoJournal*, 69 (4), pp. 211–221.

Groom, Q. J., O'Reilly, C. and Humphrey, T. (2014). Herbarium specimens reveal the exchange network of British and Irish botanists, 1856–1932. *New Journal of Botany,* 4 (2), pp. 95–103.

Haklay M. (2013). Citizen science and volunteered geographic information: overview and typology of participation. In: Sui D.Z., Elwood S., Goodchild M.F., eds. *Crowdsourcing geographic knowledge: volunteered geographic information (VGI) in theory and practice*. Berlin: Springer, pp. 105–122.

Haklay, M., Antoniou, V., Basiouka, S., Soden, R., and Mooney, P. (2014). Crowdsourced geographic information use in government, Report to GFDRR (World Bank). London.

Howe, J. (2009). Crowdsourcing: Why the Power of the Crowd Is Driving the Future of Business. *Crown Publishing Group*.

Hutt H., Everson R., Grant M., Love J., and Littlejohn G. (2013). How clumpy is my image? Evaluating crowdsourced annotation tasks, in 2013 13th *UK Workshop on Computational Intelligence (UKCI),* pp. 136–143.

Jordan, R., Ballard, H., & Phillips, T. (2012). Key issues and new approaches for evaluating citizen-science learning outcomes. *Frontiers in Ecology and the Environment* 10 (6), pp. 307–309.

Lintott, C. J, Schawinski, K, Slosar, A, Land, K, Bamford, S, Thomas, D, Raddick, M. J, Nichol, R. C, Szalay, A, Andreescu, D, Murray,P, and Vandenberg, J. (2008). Galaxy Zoo: morphologies derived from visual inspection of galaxies from the Sloan Digital SkySurvey. *Monthly Notices of the Royal Astronomical Society.* 389 (3), pp. 1179–1189

McKinley, D.C., Miller-Rushing, A.J., Ballard, H.L, Bonney, R., Brown, H., Evans, D.M., French, R.A., Parrish, J.K., Phillips, T.B., Ryan, S.F., Shanley, L.A., Shirk, J.L., Stepenuck, K.F., Weltzin, J.F., Wiggings, A., Boyle, O.D., Briggs, R.D., Chapin III, S.F., Hewitt, D.A., Preuss, P.W., Soukup, M.A. (2015). Investing in Citizen Science Can Improve Natural Resource Management and Environmental Protection. *Issues in Ecology* 19.

Maisonneuve, N., Stevens, M., Niessen, M.E., Hanappe, P., Steels, L. (2009) Citizen Noise Pollution Monitoring. *In The Proceedings of the 10th International Digital Government Research Conference*.

Newman, G., Wiggins, A., Crall, A., Graham, E., Newman, S. and Crowston, K. (2012).The future of citizen science: emerging technologies and shifting paradigms. *Frontiers in Ecology and the Environment,* 10 (6), pp. 298–304.

Nichols, J. D. & Williams, B. K. (2006). Monitoring for conservation. *Trends in Ecology & Evolution,* 21 (12), pp. 668–673.

Nicholson E., RYAN J. & Hodgkins D. (2002). Community data - where does the value lie? Assessing confidence limits of community collected water quality data. *Water Science and Technology,* 45, pp.193–200.

Nov, O. (2007). What Motivates Wikipedians?, *Comunications of the ACM.* 50 (11), pp. 60–64.

Nov, O., Arazy, O., & Anderson, D. (2010). Crowdsourcing for science: understanding and enhancing SciSourcing contribution, Position paper: *ACM CSCW 2010 Workshop on the Changing Dynamics of Scientific Collaborations*.

Nov, O., Arazy, O., & Anderson, D. (2011). Technology-Mediated Citizen Science Participation: A Motivational Model. In *Proceedings of the AAAI International Conference on Weblogs and Social Media (ICWSM 2011).* Barcelona, Spain.

Okolloh, O. (2009) Ushahidi or 'testimony': Web 2.0 tools for crowdsourcing crisis information. Participatory Learning and Action. *IIED Publications Database*, 59, pp. 65–70.

Pant, R. B. (2009). The Social Media Marketing Mix (The 4 "P's"). Retrieved January, 26, 2012 from http://ritubpant.com/social-media-marketing-mix/

Pfeffer, M.J. & Wagenet, L.P. (2007). Volunteer Environmental Monitoring, Knowledge Creation and Citizen-Science Interaction. In J. Pretty, A. Ball, T. Benton, J. Guivant, D. R. Lee, D. Orr, M. Pfeffer, and P. H. Ward, *The SAGE Handbook of Environment and Society.* SAGE, 640p.

Ponciano, L., Brasileiro, F., Simpson, R. and Smith. (2014). A. Volunteers' Engagement in Human Computation Astronomy Projects. *Computing in Science Engineering*, vol. Early Access Online.

Preece, J. (2002). Supporting Community as Building Social Capital, *Comunications of the ACM.* 45 (4), pp. 37-39.

Quinn, A. J. & Bederson, B. B. (2009). A Taxonomy of Distributed Human Computation, *University of Maryland.*

Raddick, M. J., Bracey, G., Carney, K., Gyuk, G., Borne, K., Wallin, J. & Jacoby, S. (2010). Citizen Science: Status and Research Directions for the Coming Decade. In *astro2010: The Astronomy and Astrophysics Decadal Survey,* 2009, p. 46.

Raddick, M. J., Bracey, G., Gay, P. L., Lintott, C. J., Murray, P., Schawinski, K., Szalay, A. S. and Vandenberg, J. (2010b). Galaxy Zoo: Exploring the Motivations of Citizen Science Volunteers. Astronomy Education Review, 9 (1).

Reid, C., Marshall, J., Logan, D., Kleine, D. and Dean, A. (2012). Coral Reefs and Climate Change. The guide for education and awareness. Published by CoralWatch, The University of Queensland. 264p.

Sheppard, S. A. & Terveen, L. (2011). Quality is a Verb: The Operationalization of Data Quality in a Citizen Science Community. In *Proceedings of the 7th International Symposium on Wikis and Open Collaboration*. New York, NY, USA, pp. 29–38.

Soares, M.D. (2011) Employing Citizen Science to Label Polygons of Segmented Images. (doctoral dissertation), National Institute For Space Research.

The Royal Society. Knowledge, Networks and Nations: Global scientific collaboration in the 21st century, 113p.

Tweddle, J.C., Robinson, L.D., Pocock, M.J.O. & Roy, H.E. (2012). Guide to citizen science: developing, implementing and evaluating citizen science to study biodiversity and the environment in the UK. *Natural History Museum and NERC Centre for Ecology & Hydrology for UK-EOF*.

Uchoa, A. P., Esteves, M. G. P., and Souza, J. M. (2013). Mix4Crowds - Toward a framework to design crowd collaboration with science, in *2013 IEEE 17th International Conference on Computer Supported Cooperative Work in Design (CSCWD),* pp. 61–66.

Wenger, E., Mcdermott, R. and Snyder, W. M. (2002). Seven Principles for Cultivating Communities of Practice. HBSWK Pub.

Wiggins, A. & Crowston, K. (2010). Developing a Conceptual Model of Virtual Organizations for Citizen Science. *International Journal of Organizational Design and Engineering,* 1, pp. 148–162.

Wiggins, A. & Crowston, K. (2011) From Conservation to Crowdsourcing: A Typology of Citizen Science. In *Proceedings of the 2011 44th Hawaii International Conference on System Sciences*, Washington, DC, USA, pp. 1–10.

Wiggins, A. & Crowston, K. (2012). Goals and Tasks: Two Typologies of Citizen Science Projects. In *Proceedings of the Fourth-fifth Hawaii International Conference on Systems Sciences* (HICSS-45).

ENDNOTES

[1] http://flusurvey.org.uk/
[2] https://www.ushahidi.com/
[3] http://earthquake.usgs.gov/data/dyfi/
[4] http://www.wikiaves.com.br/
[5] http://climatecolab.org/
[6] https://www.planethunters.org/
[7] http://centerforgamescience.org/
[8] http://www.galaxyzoo.org/
[9] http://www.fold.it/