Citizen science in the Internet era

Executive summary

Citizen science is by definition carried out by citizens who are not « scientific professionals ». It is changing rapidly, as a result of the democratization of knowledge, new and faster communication technologies and increased open access to information.
A first - and major- component of citizen science is the 21st century version of the long established « Community-Based Participatory Research ». CBPR is usually performed by people with little formal scientific training participating in research projects coordinated by trained experts. It now takes the form of many projects across the world involving millions of people and billions of data items collected.
A second emerging component involves individuals having a solid scientific background, but working outside the walls of the usual professional research systems. They do science in public or private virtual communities or in private settings. This category of citizen science is referred to, here, as "Beyond The Walls Research" (BTWR).

In the present Internet era, the potential value of these approaches to research is high: CBPR may contribute to improving public understanding of science and the scientific method, and can thus play a role in democratizing knowledge and learning. BTWR offers an opportunity to advance knowledge and innovation in ways that were previously inaccessible to the academic, government or industrial organizations of research, and constitutes an opportunity – widely used by industry - to discover talented individuals outside the standard research system.

Alongside these potential benefits come risks, especially around the evaluation of results stemming from CBPR and BTWR. These results are often disseminated through diverse channels outside the traditional peer-review system. There are also risks that ethical guidelines and safety regulations that apply to research carried out in the standard professional framework are not followed by those engaged in this new citizen science and, therefore, there is a need for anticipation and control.

Finally, the development of citizen science requires an increased effort in the scientific training of the citizen at all ages, starting at school, and the integration of perspectives in the arts and humanities, law, education, social sciences and ethics as well as natural sciences and engineering.

Recommendations

The detailed recommendations are at the end of the statement.

- Rethink scientific education to equip students to undertake citizen science or professional research later on.
- Take action to avoid or mitigate ethical lapses and security risks of citizen science.
- Promote the co-development of citizen science and laboratory-based research.
- Enable citizen scientists to adopt existing culture of reporting and assessing scientific contri butions.
- Create specific funding programs for citizen science.
- Promote information systems to document themes and results of citizen science.

Introduction

The concept of a professional research system in the modern sense has not always existed. Many early scientific investigations were carried out by isolated individuals collaborating and exchanging ideas across the world. Examples of structured and systematic organization of research were the creation of observatories in astronomy and the development of botanical gardens in life science. From the second half of the 19th century, scientific research planted its roots mainly in universities, specialist institutions and industrial laboratories, which provided the researchers with the necessary technical and intellectual environment. Research laboratories cannot work in isolation. The necessity of cooperation between basic research teams (often in universities) of different specialties, and their partners in industry or government was soon acknowledged and supported by a variety of organizational means.

The second half of the 20th century saw the rise of "citizen science". In a majority of situations, citizen science was carried out by citizens working in more or less close collaboration with universities, research institutions and industrial laboratories.

In the 21st century, the citizen is enjoying increased opportunities to engage more deeply than before in scientific research. This is the consequence of:

- The democratization of knowledge, linked to the general pursuance of higher levels of education since World War II.
- The Internet revolution accompanied by the dissemination of high-performance electronic equipment and analysis software giving ordinary citizens access and the ability to report, analyze, visualize and even produce data (e.g. in the environmental field).
- The broad move towards open science allowing public access to data, scientific research methods – essential for reproducible science – and to results of this research.

This statement makes recommendations on two categories of "citizen science".
The first one, which is predominant, is participatory research done by citizens who have not necessarily received training in scientific research. It was this activity that has been historically named "citizen science". Here, we denote it as "Community-Based Participatory Research (CBPR)"[1] . There are many historical examples, like those of Buffon and Lacépède in France who relied on a vast network of correspondents for their "Histoire Naturelle" or like Darwin in the United Kingdom.
A second and more recent category of citizen science involves scientifically trained individuals working in isolation, or in virtual communities, to develop projects outside established controlled environments (university, government or industry research system). We refer to this category of citizen science as "Beyond The Walls Research" (BTWR).

Herein, the Academies of Sciences assess these research orientations, their utility, the quality of the new practices, and propose a set of recommendations for a better recognition and integration of these efforts. These recommendations are intended to achieve the full potential and guarantee the quality of all kinds of "citizen science".

New trends in citizen science

At this stage it is useful to describe some of the trends that characterize citizen science, noting that its reach and characteristics differ greatly by discipline, reflecting the wide range of disciplinary practices that exist across the science base. This is conveniently accomplished by successively considering the two components identified previously. Then we conclude by analyzing the great potential of citizen science, its opportunities and risks.

1. CBPR in this text is not limited to a type of "action research" as defined in http://www.bris.ac.uk/education/study/continuing-professional-development-cpd/actionresearch/

An established category of citizen science: “Community-Based Participatory Research”
There has been a considerable expansion of CBPR in domains covering biodiversity data collection (e.g. www.inaturalist.org), astronomy (e.g. www.zooniverse.org, which also hosts projects on many other topics), weather data collection (as exemplified by the Met Office in the UK[2]), and air quality observation. The partnership between citizens and professional researchers has resulted in thousands of projects across the world involving millions of people and billions of collected data items. Some of these large-scale projects feature sophisticated systems for ensuring data quality (see: ebird.org, www.iNaturalist.org, www.ispotnature.org) that involve a combination of machine learning and vision, data visualization and human expertise. Once the quality of the data is assured, it is transferred into major data repositories such as – in the US - the Global Biodiversity Information Facility where it is made available to the scientific community.
CBPR has in particular taken considerable importance in medicine. It is now difficult to conceive medical research, either epidemiological, diagnostic or therapeutic, without patients directly participating in the research effort. This has led to the emergence of the patient-expert notion, often via patient associations (AIDS is a good example of this engagement). Moreover, patients can share data amongst themselves if they wish, while doctors cannot do so without their approval. This opens new opportunities in epidemiological research, and new ethical concerns as well.

An emerging category of citizen science: “Beyond The Walls Research”
The 21st century is seeing the rise of new forms of citizen science. They involve non-professional scientists (i.e. they are not scientists formally affiliated to, or paid by, university, government or industrial institutions) as in CBPR. However, by contrast to most of CBPR, the participants in this kind of citizen research are people trained in science (often holding a PhD, or a Master degree) and generally competent in using innovative technologies and methods. This research is done “beyond the walls” of university, government or industry research laboratories. BTWR is often loosely linked to conventional research laboratories or acts as a source of patents and startups through its interactions with industry and business.

A first class of BTWR comprises individuals or small groups responding to challenges and commissions. Resorting to contests to resolve complicated problems deemed important, by openly calling upon the talents of others is nothing new. A historical example is the Longitude Prize, created in 1714 by an English Parliamentary committee; advised by Isaac Newton and Edmond Halley, it rewarded the challenge of accurately measuring longitude. But, here again, the internet access has changed the scale of this practice by permitting worldwide dissemination of contest subjects, facilitating the creation of geographically scattered ephemeral teams and easily making datasets available to everyone[3]. This approach is particularly active in data science, an essential field for large digital companies that, with their enormous financial resources, play a major role in setting up these contests and harvesting their results. BTWR is also quite active in the domains of space and transportation technologies.

A second class of BTWR projects triggered by the “Do It Yourself” (DIY) movement concerns fields in which the advanced tools, techniques or software are readily available, often via the Internet. Hence, isolated individuals or small groups - physical or virtual - can get involved in ambitious projects. This is exemplified in domains ranging from space applications, biomedical devices, or biology with the development of genetically modified organisms (“DIY biology”). There is clearly a serious issue of security and safety when results of these activities may have broad implications for the lives of others.

Potential developments of citizen science

The present movement towards open science, which Academies support actively, is a new opportunity for citizen science. Citizens already do or will soon enjoy access to resources that were pre-

2. See: https://blog.metoffice.gov.uk/2016/07/05/encouraging-a-new-generation-of-weather-observers/
3. See for example https://www.kaggle.com/competitions which lists a variety of open contests, the prizes offered and the numbers of teams/individuals participating. Other examples abound in the space industry with prizes up to several millions dollars.

viously available almost uniquely to laboratory-based researchers: a first key resource will be the full and free access to (most of) the scientific literature. The principles of “reproducible research” provide that the details of the research protocols, source data and codes of the programs – if any – should be described with sufficient details to facilitate the dissemination of experimental know-how. These resources include powerful analysis techniques, including artificial intelligence tools, which are of very wide applicability.

CBPR and BTWR activities can also be predicted to grow because they correspond to citizens’ desire for freedom, inclusion, and autonomy, with the technical possibilities offered by the Internet and other communication technologies powered by vast resources under private control. This movement is observed for almost all human activities, and there is little rationale to believe that research will be an exception.

The predictable expansion of citizen science, particularly in the BTWR category, already has, and will have, important economic consequences. Because of its potential for innovations and flexibility, BTWR is, and will be, part of industrial developments. Industry cannot but be attentive to these trends, in light of its own interests in terms of intellectual property and patent protection. These activities are also a source of start-ups in digital technologies as well as in other fields, e.g. space industry and synthetic biology. Some expected consequences of these developments are positive while others raise questions and worries.

In all these situations, it is extremely important that there are mechanisms for members of the public, the media and others to assess scientific announcements on the basis of the quality and robustness of the research methodology. One can imagine a development of the several forms of citizen science into a professionally monitored global quality control system, a “poor science” detector, providing the considerable resource and diversity of knowledge required to flag cases of suspected poor scholarship findings.

Opportunities

- The increasing number of non-professional scientists involved in research activities will allow an improved appreciation of science by a larger more diverse number of people for the common good, augment trust in science, and strengthen the place of scientific expertise in public decision-making processes.
- Citizen science undertakings can enable the integration of knowledge systems from different communities (e.g. Indigenous communities in North America) and the gathering of data more quickly and/or more economically in some fields, or even to have access to research projects simply unimaginable in the within-the-walls context. Beyond that, a harmonious relationship between the two research modalities could yield even more fruitful benefits.
- Citizen science is a new opportunity to discover talented individuals outside conventional scientific career structures and possibly new ideas to answer the big questions of the moment. This opportunity is widely used by industry, particularly in information and space technologies.
- Citizen science can be utilized to resolve major challenges (e.g. seti@home).

Concerns

- Citizen science should not be a substitute for professional trained scientific workers.
- Citizen science may lack standards mainly due to the absence of an independent reviewing system. Unchallenged poor quality findings could diminish public confidence in science more generally.
- The problem of replicability has already become a big issue in academic science and specific precautions have been suggested to curtail the flood of nonreplicable research reports. These precautions will have to be adapted to handle the outcome of citizen science projects (CBPR and BTWR).
- It is potentially worrying that research could be too easily undertaken without control of the ethical and moral frameworks and the safety regulations imposed on “traditional” institutions in key societal matters (e.g. genetics and pathogenic organisms).

Six recommendations

The main recommendations are the followings, which are all interrelated.

■ Rethink scientific education to equip students to undertake citizen science or professional research later on

In a world that is being transformed by information sciences and technologies, there is a need to rethink education and to develop new ways to learn throughout life, and access rational, easily accessible and validated multidisciplinary knowledge.
This will require the following actions:

- Develop and implement – as soon as possible and as early as primary school – new ways of learning and new methods of working together efficiently to obtain quality results. Schools will need to be given the resources in terms of science teachers and equipment to initiate students into the practice of science.
- Train pupils and students, as early as possible, in abstract and numerical reasoning skills because these are fundamental to grasp concepts as induction, deduction, probabilities, nonlinear relationships and other basics of empirical research.
- Encourage established institutions to play an important role in validating novel training and information tools (such as e-encyclopedias), updating knowledge in disciplinary fields and making it accessible to the public.

■ Take action to avoid or mitigate ethical lapses and security risks of citizen science

Existing control procedures need to be adapted to citizen science, to avoid possible misappropriation, and therefore ensure that ethical guidelines and safety rules are followed in citizen science, especially in the fields of biology and medicine.

■ Promote the co-development of citizen science and laboratory-based research

A close interaction of citizen science, including training, with the professional scientific community and personnel is mutually beneficial and important for the validation of results. It must be carried out with trust and mutual respect. Ideally, every involved citizen should have a minimal understanding of what is at stake scientifically and technologically. Conversely, laboratories should be attentive to questions raised by the community.
This necessitates that:

- Specific funding and personnel be allocated to mentoring activities and to the dissemination of scientific methodology and the monitoring of research quality and reproducibility.
- Human and social sciences be integrated to help identify factors and strategies for a fruitful co-development of citizen and laboratory based research.

■ Enable citizen scientists to adopt existing culture of reporting and assessing scientific contributions

The many reflections on improving research assessment and quality of results dissemination should be extended and/or adapted to include citizen science, taking full account of the specificity of this type of research. Innovative methods are needed which provide an independent assessment of results and dissemination channels that will guarantee an acceptable level of quality. The present development of methods helping users to identify fake news on the web should also target research results. One can imagine a managed development of citizen science and appropriate tools such that citizen science is able to monitor itself, and establishes comparable standards of review and robustness which are applied to traditional laboratory environments.

■ Create specific funding programs for citizen science

Citizen science, in many fields mentioned in the introduction, brings invaluable data and expertise. The value, in terms of money, of the corresponding workforce is difficult to estimate but is likely to be quite large. Conversely, national and international agencies might consider finding additional financial support for citizen science. Specific international financing measures could be coordinated by the Academies in fields of shared worldwide interest, such as, the Sustainable Development Goals.

Within this, it will be important to consider the longer-term implications of the fact that some fields are more amenable to citizen science activities than others e.g. those that can be pursued only through access to expensive equipment or a safe laboratory environment.

■ Promote information systems to document themes and results of citizen science

Move towards comprehensive information on citizen science (CBPR and BTWR) projects carried out in the G7 countries and elsewhere. This might be achieved by creating an international common platform for the collection and dissemination of this information, for example under the aegis of the International Science Council (ISC). This would enable citizen science itself to become an object of research for the human and social sciences.

General references

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