Integrating Research into Society within a Cooperative/Collaborative Framework: C-Research

Luca MONTABONE

Space Science Institute, Boulder, CO, USA
Laboratoire de Météorologie Dynamique, UPMC, Paris, France
University of Oxford, Department of Physics, Oxford, UK

lmontabone@SpaceScience.org

ABSTRACT

This position paper explores one possible framework within which the integration of research and problem solving with education and outreach may lead individuals to achieve inquiry-based personal knowledge. Research is considered as a 'cognitive tool'. It is argued that the direct participation of non-professional researchers in dedicated research projects facilitates the understanding of the process by which knowledge and its applications are obtained. I briefly review some of the concepts of research that have been recently developed, such as citizen research, community research, and participatory research, before introducing the more generic concept of 'c-Research' (where the 'c' stands for 'cooperative' and 'collaborative'). I describe the key differences between the c-Research concept and the ordinary research, and conclude with some hints on the implementation of a c-Research structure.

Keywords: c-Research, Cooperative Research, Collaborative Research, Research and Society, Capacity Building, Citizen Research, Community Research, Citizen Science.

1. INTRODUCTION

Research is one of the structured and systematic processes human individuals can use to acquire new knowledge. With the development of the scientific method, the research process gained a truly novel structure. The investigation of Nature and the application of results to problem solving exponentially increased their successes. Despite this, a proper integration of research (as "systematic search for new knowledge") into society is far from being accomplished.

In principle, any human being can practice a research process to foster his own knowledge. However, the need to learn and master structured and systematic approaches, as well as limitations on motivations, resources and time, often restrict the practice of research to a relatively small number of dedicated individuals, who work to advance knowledge in specific areas that benefit parts of society or society as a whole. Universities are one of the best examples of institutions where scholars are professional researchers, who markedly focus their investigations at the fundamental level. Applied research can be the activity of non-academic institutions such as companies, government-related bodies, think-tanks, and so on.

Relatively speaking, there is not a strong tendency towards inquiry-based knowledge in the everyday life of an ordinary person. The flow of new knowledge is largely one-way, moving from those who acquire it through professional research to those who learn or simply use it. By doing so, society chooses to delegate what is fundamentally a general process of knowledge-acquisition to a group of selected individuals, *de facto* cutting it off from everyday life.

These considerations can be applied to different countries and societies around the world with a great degree of distinction. It is obviously very different to analyze the relationship between research and society in countries such as the UK or the USA, rather than in newly industrialized countries such as India or China, or in developing countries where research may not even be noticeable at the institutional level. Nevertheless, I would argue in general that research, as a systematic process to acquire new knowledge and apply it to problem solving, can be considered as a 'cognitive tool' (see [1] for a definition derived for technology), and that the education to research can be made easier by its practice.

Research might not be for all, but it can certainly be possible for many, at several levels. An efficient way to integrate research into society is therefore highly desirable. This position paper explores one possible framework within which to achieve such integration.

2. TOWARD A NEW RESEARCH CONTEXT

The ordinary way new knowledge flows from specialists to society has been questioned and reviewed in the last two decades. An example in education is provided by the National Science Education Standards set up by the USA National Research Council in 1996, promoting an inquiry-based science rather than the learning of facts [2]. The one-stream model of specialist research feeding society with new knowledge solely through factual education and outreach does not satisfy two basic principles: 1) discovery is a cognitive delight and enrichment, and 2) the public, in addition to knowing facts, should also have the possibility to understand critically the process by which the knowledge of those facts is obtained. If these two principles are applied, it becomes manifest that the participation of the public in research can be considered as part of the development of society. Here, I intend the "public" as the part of society that is not professionally engaged in research. Ultimately, an understanding of the bases of the research process would allow more members of the public to apply this cognitive tool to everyday life, which is likely to stimulate individuals to be more critical and responsible for their choices.

3. THE RESEARCH PROCESS

How can we define what a generic (not necessarily scientific) research process is about? Identifying core elements of this cognitive tool is a necessary step towards its integration into society. The following flowchart summarizes the key characteristics of a generic research process.

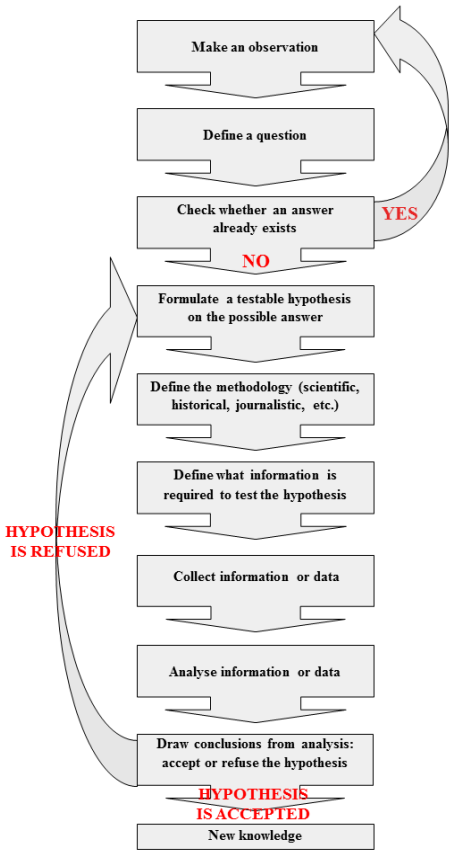

Figure 1: Flowchart of key elements of a generic research process (the 'research flow'). The continuation of the process could be the application of newly generated knowledge to problem solving or rather a return to the beginning of the process, namely asking new questions, or making new observations.

The research flow described above can be either an individual activity or a group activity, and the results can be either shared or kept for oneself. In terms of sharing the information and discussing the conclusions, the possible approaches are abundant. Openness and cooperation/collaboration have advantages that make them preferable in many cases, when the exchange of ideas, information, tools, and data at each step of the research flow helps to achieve a successful outcome.

The flowchart in Fig. 1 can be equally adapted to scientific research projects and to research based on everyday life scenarios. Let us suppose, for instance, that a family observes that the number of days of sunshine in the location they recently moved to seems large. They want to understand whether the installation of solar panels on the roof of their house can make them save money. The first step for them is to check whether there are neighbors who have already installed solar panels, and can share their experience and costs/savings. If not, they decide to test the hypothesis that, with panels of a certain size, they can reduce costs with respect to the grid energy consumption over a defined time period. They realize they need to approach the problem scientifically, by analyzing information on the insolation of their location, the local cost of grid energy, their consumption, and the cost of the solar panels. So they collect data on the historical insolation time series, and measure their energy consumption over a year, while collecting information on the cost of local grid energy in the last few years, and the cost of installing different numbers/sizes of solar panels. They need to use some simple statistical analysis to reduce the data to average values and trends. Having done that, they are able to compare the costs of installing the panels with those of consuming grid energy, taking into account the expected amount of solar energy production, and their expected consumption. The hypothesis of saving money over a defined period can therefore be tested for several sizes of the panel surface, down to a minimum. The inquiry-based decision to install a certain number of solar panels in relation to their family requirements might result in an optimized saving.

One could find many more examples where the application of research to everyday problem solving can lead to viable solutions. The key question that is at the origin of the present paper is the following: can a person with no research background learn how to properly conduct an inquiry-based analysis by participating in research projects where non-specialist contribution is encouraged? The purpose of this paper is to suggest that this is possible, although it is beyond the scope to carry out a dedicated study to provide an answer beyond the author's opinion.

4. NEW AVAILABLE MODELS OF RESEARCH

The fact that it is possible has been partly verified by some communities of professional researchers (astronomers and zoologists in particular), who have asked themselves a question similar to the one I have introduced above, namely: can a person with no research background provide valuable help to achieve novel results by participating in dedicated research projects where non-specialist contribution is encouraged? The emphasis is here on the achievement of novel results with the help of non-professionals, rather than on the personal development of non-professionals (although an outreach component is often advocated). The answer to this question can be found in the large social and scientific success obtained by 'citizen research' projects (currently better known as 'citizen science', as most of the projects have a scientific nature) and 'community research' projects around the world in the last decade or so. It is worth mentioning, actually, that the longest-running, 'volunteer remote-sensing', citizen research project (the 'Christmas Bird Count'[1]) was started by the National Audubon Society in 1900!

A satisfactory list of these projects is out of the scope of the present paper[2], and the number of publications related to these new ways of doing research is now vast. I just mention here the 2009 Report on Public Participation in Scientific Research compiled by the Center for Advancement of Informal Science Education (CAISE), which provides a clear, simple, but rather exhaustive classification of case studies divided in three major categories: contributory projects (including a large part of citizen research projects), collaborative projects, and co-created projects (including community research projects) [3]. Remarkably, all three category names start with a 'c'. The distinction is based upon the degree of participation of the public and the amount of control that non-specialists have over the different steps of the research process. Contributory projects are designed by specialists, or professionals, and the public primarily contributes data; collaborative projects are still designed by specialists, but the public can contribute data as well as it can help refine project design, analyze data and disseminate findings; co-

[1] URL: http://birds.audubon.org/history-christmas-bird-count

[2] The reader can use the project finder tool at http://scistarter.com for a comprehensive list of citizen research/community research projects

created projects are designed together by specialists and members of the public, and some of the public participants are actively involved in all steps of the research project.. A good historical review of the application of these concepts to projects in the field of ecology is provided by [4].
This classification almost automatically divides research projects with public participation also according to the scale of the project and the number of participants involved. Co-created projects, such as those typical of community research or 'participatory action research' ([5]), are necessarily limited in the number of participants, whereas contributory projects, such as those typical of citizen science, are usually large-scale projects with thousands of participants who might be scattered in large areas or across the whole world, heavily relying on the internet. It is worth mentioning two of these large to middle-scale citizen science projects: 1) 'Galaxy Zoo' ([6]), in which many thousands of individual volunteers, without specific scientific training, help professional researchers to screen online large astronomical datasets, and 2) 'Iimbovane' ([7]), in which a few thousand volunteer school teachers and students living in rural South-Africa collect data about ants ('Iimbovane' in the local language). The importance of these two projects in the vast galaxy of citizen science projects is that the unexpected success of Galaxy Zoo allowed it to become the first of a series of projects now collected under the 'Zooniverse' umbrella, and Iimbovane is one of the first projects specifically targeting volunteers in newly industrialized or developing countries.
Finally, the classification of the projects as contributory, collaborative and co-created introduces differences which are based on the purposes of public participation. While co-created projects might have an explicit educational or problem-solving purpose, and can be designed to develop research awareness or capacity in the participants, contributory projects are usually designed to obtain novel results by screening large datasets or collect remote data, otherwise impossible with the participation of a limited number of professional researchers. Educational and capacity building scopes are usually secondary in contributory projects, at least for those steps of the research process which non-specialists do not contribute to. Outreach is usually considered important throughout the three categories, also as a way to stimulate public participation in the projects.

5. THE C-RESEARCH FRAMEWORK

In the previous section I have mentioned some of the new models of research that are being developed in a few countries around the world, and briefly described some of their characteristics. These models have more or less subtle differences and specificities, so that many different names have been created to differentiate them. 'Citizen research', for instance, becomes 'citizen science' if the research uses the scientific method, 'extreme citizen science' if no assumption is made on the literacy of the participants, or 'citizen cyberscience' if there is a massive use of technology involved. In addition, citizen research becomes 'community research' if the goal is to answer to questions rising within a specific community, and so on. Even within the same group, the boundaries are continuously pushed, because the large-scale participation of non-professionals to research is a fairly new experience, which is evolving quickly, and does not have defined rules.
Building on these specific models, and half seriously remarking that most of them have names that start with 'c', I introduce in the present section a generic framework, which I name **'c-Research'**, to be used for the purpose of integrating research into society (or, possibly, re-integrating, if one considers that in the past the distinction between professional and non-professional researchers was less marked).
Although the **'c'** in the name could represent all definitions I mentioned before, I propose that it stands for **'cooperative'** and **'collaborative'**, two adjectives that characterize research as enterprise jointly managed by all those who use it, working together according to everybody's capacity and possibility. The generic c-Research term is, therefore, intended to describe a model where society as a whole becomes directly engaged in the research process and obtain benefits out of this engagement. In my opinion, cooperation and collaboration between those who carry out research as a profession and those who accept to do it as an interest are the two distinctive features that separate this framework from the ordinary way of delegating research to professionals. Names like 'citizen' or 'community' research do not provide any specific characterization, since both professional and amateur researchers are ultimately citizens of some country and might even belong to the same community. More importantly, they appear to me as different realizations derived from the same original concepts, which are also at the core of the c-Research framework, as I detail below.
The c-Research term is extrapolated from the e-Research term (where 'e' stands for 'electronic'), which is currently adopted to indicate the use of information technology to support research (in the USA, the term cyberinfrastructure

is typically used instead) [8]. While e-Research mostly refers to highly technological infrastructures for research, c-Research refers to the wider group of subjects who carry out research within the society, being at the same time its beneficiaries. However, c-Research strongly requires the use of e-Research to facilitate the integration of the research activity into society.
Which characteristics should a c-Research project have in order to qualify as such? In my opinion, the key elements that define the c-Research activity and distinguish it from (most) ordinary research must be the following.

- It is oriented to capacity building and personal development, at least as much as to research results.
- It can be guided by professional researchers or research experts, but non-specialists participate at different levels according to skills and expertise.
- Participation is not discriminatory in any form and for any category (e.g. disabled people), within reasonable boundaries.
- Participation and coordination can be carried out at distance and virtually, if required.
- Topics are of direct interest to society (this does not imply that fundamental research is excluded! It might well be the opposite).
- Material and tools should be adapted for non-specialist use. These tools should be made as simple as possible to use (but not simpler, as Albert Einstein would probably point out)
- Results must be openly shared and made readily accessible.

The concept of c-Research as defined above incorporates several ideas that have been recently proposed and developed, such as the concept of collaboratory ([9]), open research[3], collective intelligence (see e.g. [10]), crowdsourcing[4], and volunteer thinking ([11]).
The element that uniquely characterizes the c-Research framework, and encompass the other research concepts previously described, is the ultimate goal to build an inquiry-based attitude within society by integrating research, education, problem solving, and outreach in a coherent and balanced way, using a cooperative/collaborative management approach. Such cooperation and collaboration relate to the possibility for the public to actively participate in research projects and/or to initiate research projects, as much as professional researchers.
A requirement for achieving this goal is the adoption of a two-stream model for the flow of information and knowledge, which crosses multiple, concentric and inter-connected levels of participation and expertise (see Fig. 2 for a representative diagram).
Generally speaking, in ordinary research the structure of participation and expertise is pyramidal, with professional researchers at the apex and ordinary, non-expert people at the bottom. The flow of information and knowledge is unidirectional (one-stream), from the top to the bottom. C-Research uses a different approach, based on the principles that expertise does not necessarily mean foremost knowledge, and excellence can be the result of a collaborative process rather than the achievement of skilled individuals. Ideally, therefore, participants in a c-Research project have different skills and expertise (not necessarily directly linked to the project), and contribute according to their abilities, available time, and motivations. All parts (concentric cooperative/collaborative levels, or 'c-levels') have access to the same information and can contribute with new information, possibly converted in a form that suits a particular c-level. Research experts (not necessarily professional), at the core of a project, provide guidance and research experience. Obviously, nothing prevents individuals to move inward if progress is attained (Figure 2 can be naturally visualized as a vortex). C-Research requires several c-levels to work, and all c-levels ultimately benefit.

[3] http://www.openscience.org/blog/?page_id=44
[4] http://en.wikipedia.org/wiki/Crowdsourcing

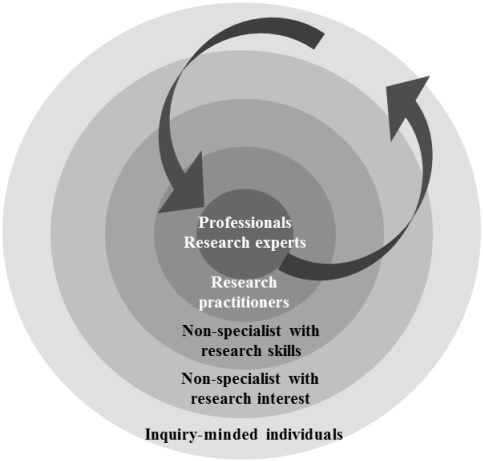

Figure 2: The concentric-level, two-stream model that characterizes the transmission of information in the c-Research framework.

6. COOPERATION VS COLLABORATION

Why c-Research takes its name from both cooperation and collaboration, instead of being identified solely by either the former or the latter?

Cooperation and collaboration have subtle but important differences, which can be exemplified using either the learning context or the corporation context. Cooperative learning, for instance, is a set of processes helping people interact to accomplish a specific goal, often controlled by a teacher, while collaborative learning is a personal philosophy which highlights individual member's abilities and contributions, often in an environment of shared responsibility and authority ([12]). In a context of corporative work[5], collaboration can be seen as departments and stakeholders sharing resources, responsibilities, information, and ways of working, while cooperation is considered as those departments and stakeholders maintaining separate mandates and responsibilities, although agreeing to do some work together to meet a common goal.

Is collaboration to be preferred over cooperation? It really depends on the context and on people! Given the general characteristics I listed in Section 5, it would be hard to clearly separate collaborative and cooperative aspects. The requirement of a guidance provided by a professional researcher (or simply an 'expert') within a c-level model is more typical of a cooperative approach, whereas the requirements of openness and accessibility of information and results are rather typical of a collaborative approach. Ultimately, therefore, the distinction becomes a semantic issue rather than a concept issue.

C-Research is a framework where the subjects are the individuals, the object is a question, the goal is an answer, the motivations are learning, problem-solving, personal development, and the method is a balance between cooperation and collaboration between the individuals. It is certainly not thought to substitute the standard model of research, adopted by most universities and research organizations, and supported by funding agencies, but rather to complement it.

7. SUSTAINABILITY OF THE C-RESEARCH FRAMEWORK

C-Research is not an abstract concept, but a practical framework that, in the author's opinion, can be implemented to create a sustainable research structure oriented towards public research awareness. In a manner similar to how universities carry out ordinary research while providing formal education, a c-Research organization can efficaciously sustain its collaborative research activities by providing 'research consultancy' or informal 'education to research' to the public. The expertise and experience of professional c-Researchers can be used to guide non-

[5] http://brainery.net/mcblog/?p=255

professionals to carry out research by themself, to develop tools and material to facilitate the participation, and to develop transferable research awareness and skills.
We know there is great demand for formal higher education, which sustains the existence of universities. Is there an equivalent demand for hands-on research in society? Three simple considerations might suggest that this is the case: 1) the huge success of so many citizen science and community research projects, 2) the persistent request of participants in citizen science projects to have the possibility to 'go further' (check for example the high volume of activity on some of the project forums), and 3) the increasing use of the scientific method to test hypotheses related to ordinary everyday life activities (e.g. environmental-related issues). These considerations, summed with the currently growing interest in informal education (see e.g. the large availability of 'massive open online courses', or MOOCs, now even delivered by many formal universities), provide an encouraging picture for the sustainability of a c-Research model.
In relation to sustainability, it is also interesting to mention that the ever-increasing costs of formal higher education is pushing governments and universities to accept knowledge obtained with informal educational activities as worth formal credits. In the USA, for instance, "Mr. Obama's proposal urges colleges to experiment with approaches that reduce costs. The plan mentions so-called competency-based degrees, in which college credits are based not on the hours students spend in classrooms, but on how much they can show they know".[6]
Finally, the current large availability of high-quality, informal educational material, such as MOOCs, is reassuring when one takes into account the possibility that non-specialist participate in research projects without following a proper academic training. Even in the absence of formal teaching, they are now able to informally build basic subject expertise using online resources. The c-Research professionals, therefore, can focus on the personal/skill development and guidance, rather than on subject teaching, improving the uniqueness of the model.

7. LEARNING THROUGH C-RESEARCH

I started this paper defining research as a cognitive tool. It is therefore necessary to spend a few words in this section to describe the possibilities offered by the c-Research approach to learning.
The objective of c-Research, as stated in Section 5, is personal development at least as much as research results. In this context, c-Research can produce informal education through research training. Non-professionals participating in guided or facilitated research projects will learn the basics of the research methodology, develop hands-on skills ('learning by doing'), and test their suitability for a possible career in research. The educational experience has the possibility to develop within a trusted team dynamics, if the principles listed in Section 5 are followed. Individual and group recognition are also important factors, which can highly stimulate both non-professionals and professionals to engage within this framework. Achievements and informal training can be certified using currently available badge systems, e.g. Mozilla Open Badges. Formal education provides certification by degrees, but there is no reason why informal achievements cannot be recognized. Furthermore, the potential for informal education to be recognised as part of the main stream learning is very high, as mentioned in Section 6.
The c-Research approach, as generally defined in Section 5, does not set specific constraints on the size of the working team or the way the team members interact (i.e. physically at a defined location, or virtually at distance). In this respect, some contributory projects that fall in the category of citizen science, or co-created projects falling in the category of community research, can well be considered c-Research. Nevertheless, the key characteristic and educational opportunity of c-Research (i.e. personal development within a collaborative context) are implemented at best, in my opinion, when using relatively small teams, so that each member has the opportunity to be individually mentored throughout the team work experience. Finally, the value of operating virtually at distance is that professionals and non-professionals can interact from their locations, with highly reduced physical barriers, which increases advantages, for instance, for disabled people, or for people living in relatively isolated locations.
Once more, I claim that it is beyond the scope of this paper to provide more details on the concept of learning through c-Research. I recognize it is necessary to analyze the characteristics, feasibility, and advantages of such approach with real case studies. I would like to mention, however, one recent project that can be recognized as one of such case studies, and proves that learning through a c-Research approach has a high potential. I am talking

[6] Citation from http://www.nytimes.com/2013/08/22/education/obamas-plan-aims-to-lower-cost-of-college.html?pagewanted=all&_r=0#

about the "Galaxy Zoo Quench"[7], one of the Zooniverse projects, which claims to make people experience science from beginning to end. The project started as contributory with a large number of participants and ended with a reduced number collaboratively working on data analysis and paper writing. Results from this experience will be published in the literature in the forthcoming future.

8. FINAL REMARKS

The basic principle of the c-Research framework, as discussed in this paper, is that everyone can have interests, skills, and competences to contribute to acquire new knowledge through research by cooperation or collaboration with professional researchers or research experts. C-Research, therefore, excludes research done individually or only by professional researchers. This framework is used to allow the integration of research, considered as a cognitive tool, into society, to the advantage of people's personal and skill development.
Here, research is seen as a methodology, defined by the flowchart of Fig.1. It can equally apply to science, humanities, journalism, or everyday life scenarios. In this respect, 'c-Science' is the application of c-Research to study the natural world using the scientific method.
The model of implementation of an operative c-Research structure, as well as the problems of funding, go beyond the purpose of this paper, and may be the objective of future work.
To conclude, I would like to anticipate a possible answer to a legitimate question the reader might ask at this point, namely: is c-Research a second-tier research, or a 'C-quality' research, compared to the 'A-quality', excellent research advocated by most research organizations? The Galaxy Zoo citizen science project, which has some of the characteristics of a c-Research project, has published more than 20 papers in peer-reviewed publications to date. In particular, one of the key discoveries was specifically made by the volunteers (the 'Green Pea' objects, see [13]). Finally, groups of volunteers who participated in the project set up their own research projects. Not to mention the success of other projects, such as 'Foldit', the protein folding game that helped to solve the structure for an important enzyme found in the HIV virus ([14]). Many more examples of research papers written thanks to non-specialist volunteers, and discoveries made by non-specialists, could be listed.
In this paper, I mentioned several different research concepts, and discussed different purposes. C-Research wants to be a generic, ideal, and inspiring framework, within which real projects develop with all possible nuances, but with only one common denominator: if research is not for everybody, it can certainly be for many, and many should have the possibility to enjoy it and to practice it, even in their everyday life. By doing so, I believe research can be integrated in society, and society as a whole can benefit from the intellectual advantages of research, much more than merely use its products.

9. ACKNOWLEDGEMENTS

The ideas described in this paper have emerged after long conversations with many people whom I am indebted to. In particular, I would like to thank Héloïse Ruaudel, John Kingston, Giacomo Correnti, Will Flynn, Elisa Carboni and Henriette Korthals-Altes for their contributions and encouragement. I am grateful to Melissa Dennison and Gaell Mainguy for providing feedback and editing skills, and to Sally Jordan, Francois Forget and two other anonymous reviewers for their useful and encouraging reviews during the preparation of an earlier version of the manuscript. Such earlier version has been presented to the 2nd International Symposium on Integrating Research, Education, and Problem Solving (IREPS 2012) in Orlando (FL), USA, March 2012. My participation to that conference, and therefore the presentation of my paper, has been made possible only thanks to the funding provided by the Open University Associate Lecturer Development Fund in 2012.
Since the presentation of the early version of this paper, the present manuscript has undergone deep modifications which changed it by more than 50%.

[7] URL : http://quench.galaxyzoo.org/#/

9. REFERENCES

[1] D.H. Jonassen, **Technology as Cognitive Tools: Learners as Designers**, ITForum Paper#1, 1994. (http://it.coe.uga.edu/itforum/paper1/paper1.html)

[2] National Committee on Science Education Standards and Assessment; National Research Council. **National Science Education Standards**, National Academy Press, Washington DC, 1996. (http://books.nap.edu/catalog.php?record_id=4962).

[3] R. Bonney, et al., **Public Participation in Scientific Research: Defining the Field and Assessing Its Potential for Informal Science Education**. Center for Advancement of Informal Science Education (CAISE) Inquiry Group Report, Washington, DC, USA, 2009. (http://caise.insci.org/news/79/51/Public-Participation-in-Scientific-Research/,resources-page-item-detail)

[4] Miller-Rushing, A., Primack, R., and Bonney, R. The history of public participation in ecological research. Frontiers in Ecology and the Environment 10: 285–290, 2012.

[5] Cornwall, A. and Jewkes, R. **What is participatory research?** Social Science & Medicine, 41(12), 1667-1676, 1995.

[6] Raddick, J., et al. **Galaxy Zoo: Exploring the Motivations of Citizen Science Volunteers**. Astronomy Education Review, 9, 010103-1, 2010.

[7] B. Braschler, **Successfully Implementing a Citizen-Scientist Approach to Insect Monitoring in a Resource-poor Country**, BioScience 59(2): 103-104, 2009. DOI: http://dx.doiorg/10.1525/bio.2009.59.2.2

[8] UK National e-Science Centre, **Defining e-Science**, http://www.nesc.ac.uk/nesc/define.html

[9] Wulf, W. **The collaboratory opportunity**. Science, 261, 854-855, 1993

[10] S. Rasmussen and N.L. Johnson, **Symbiotic Intelligence and the Internet: A Deeper Overview**. Presented at the 6th Santa Fe "Chaos in Manufactuing" Conference, April 1, 1998. (http://collectivescience.com/deeper_overview.html)

[11] F. Grey, **Viewpoint : The age of citizen cyberscience**, CERN Courier, April 29, 2009. (http://cerncourier.com/cws/article/cern/38718)

[12] Panitz, T., **A Definition of Collaborative vs Cooperative Learning**, 1996 (http://www.londonmet.ac.uk/deliberations/collaborative-learning/panitz-paper.cfm)

[13] C. Cardamone et al., **Galaxy Zoo Green Peas: Discovery of A Class of Compact Extremely Star-Forming Galaxies**. MNRAS, 399, 1191, 2009.

[14] F. Kathib et al., **Crystal structure of a monomeric retroviral protease solved by protein folding game players**. Nature Structural & Molecular Biology 18, 1175-1177 doi:10.1038/nsmb.2119, 2011.