Cos4Cloud
Co-designing Citizen Observatories Services for the European Open Science Cloud

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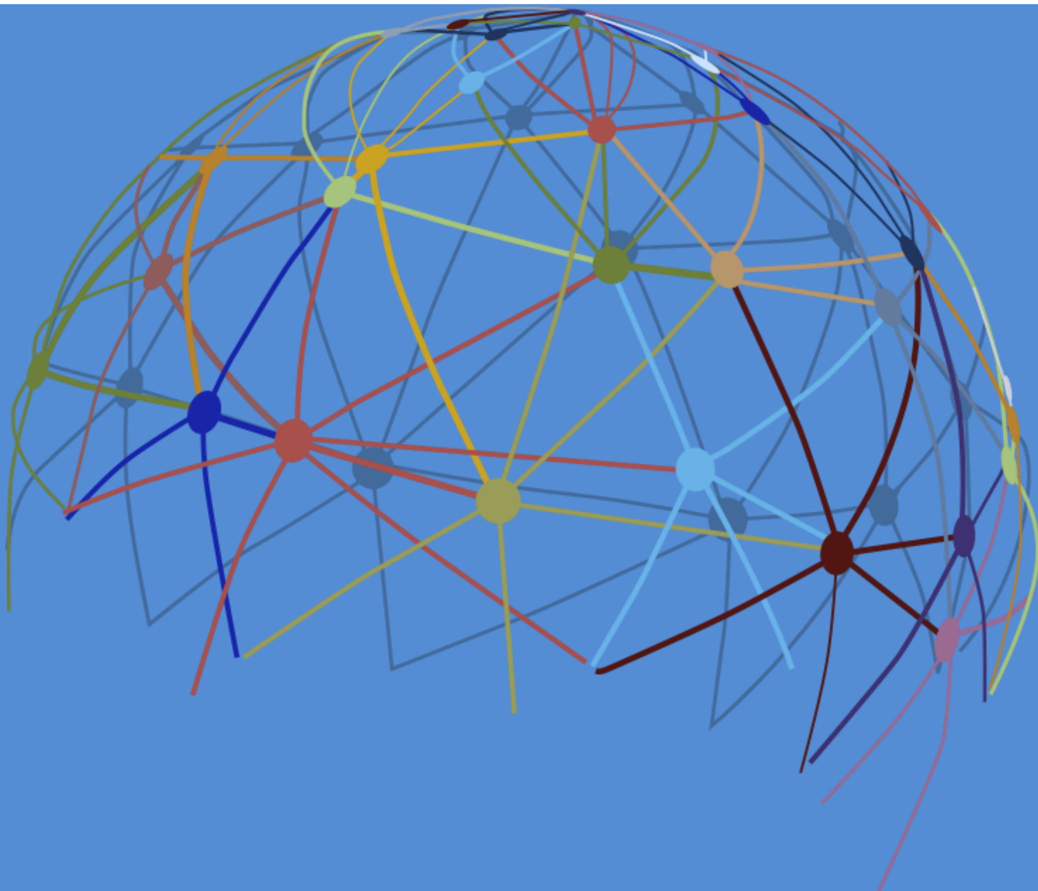

CITIZEN SCIENCE & ENVIRONMENTAL EDUCATION FOR SUSTAINABILITY

ONLINE
TRAINING
COURSE

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Module 1

CITIZEN SCIENCE:
BASIC CONCEPTS, APPROACHES AND PRACTICES

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Contents

In this Module..

The first module of the Training Course attempts **to define** and **delimit** the field of **Citizen Science (CS)**.

This is done by citing various **definitions** of CS, providing a **historical review** of events that determined its genesis and development to date and through the presentation of the different **ways** in which citizens are **involved** in CS practices, with reference to the factors that **motivate** them to participate in CS activities, a discussion on the **benefits** derived from disseminating and implementing CS, a summary of the **basic principles** guiding it and, finally, an initial attempt to examine its relationship with **education**.

All the above are approached in Module 1 as answers to the following **questions**:

- *What is the definition of ''Citizen Science'' (CS)?*
- *How did CS begin and develop?*
- *How are citizens involved in CS activities and programmes?*
- *What are citizens' motivations for participation in CS?*
- *What are the benefits from the development of CS?*
- *What are the principles of CS?*
- *How is CS connected with education?*

Expected Learning Outcomes – Goals

Upon completion of Module 1 you should be able to:

- ✓ Define the **concept** of CS based on its dimensions
- ✓ Recognize **milestones** in the development and formation of the field of CS
- ✓ Name **forms of CS**, **fields of application** and **modes of citizen participation** in it
- ✓ State the **basic principles** of CS
- ✓ List the **benefits** for science and research, society and citizens, from disseminating the implementation of CS
- ✓ Explain the relationship of CS with **education** and **learning**

Keywords

- Citizen Science
- Opening up of science to society
- Participatory research
- Forms of participation in CS
- Motivations for participation in CS

1. Citizen Science: Basic concepts, approaches and practices

1.1. What is the definition of Citizen Science?

The term **Citizen Science (CS)** encompasses a wide range of actions and practices that attempt to connect **citizens** with **scientific research**. Understandably, then, CS can reasonably be seen as a very promising concept that arouses the interest of the scientific community, politics, education, and naturally the citizens themselves. It is a modern, multidimensional and integrated concept, expressing many needs, raising various expectations, and encompassing different visions. It is, therefore, a dynamic, evolving concept. In this module an attempt is made to characterize it, based on the different **definitions** proposed to date.

The term **Citizen Science** first appears in the 1990's, coined by British sociologist **Alan Irwin** and American ornithologist **Rick Bonney**, two pioneering founders of the field. Both attempted to define the field of Citizen Science (CS) independently with Irwin (1995) focussing on one of its dimensions, namely the **opening up of science to society and the general public**(''science *for* the people''), and Bonney (1996) on a second, different, one, the **voluntary participation of ordinary citizens in scientific knowledge processes** ("science *by* the people").

In one of the first attempts to define CS, Lewenstein (2004) refers to three pursuits that characterise its practices, all of which involve the **engagement** of either lay people or (professional) scientists/researchers, in research and in science-based decision-making. Specifically, CS seeks to: a) **engage citizens** in scientific processes of data collection, processing and interpretation, b) **involve citizens** in decision-making about public issues that have technical or scientific components, and c) **engage research scientists** in corresponding democratic processes.

Another characteristic dimension of the CS field referred to is: **collaboration between citizens and scientists.** This aspect is also highlighted in the definition added to the Oxford English Dictionary in 2014, according to which the term CS refers to ''scientific work undertaken by members of the general public, often in collaboration with or under the direction of professional scientists and scientific institutions''.

Public participation in scientific research and collaboration between the public and scientists is also emphasized in the definition of Bowser & Shanley (2013). This definition refers, in addition, to the **motivations** for participation and the **nature** of the research: citizens participate in, and contribute to, the scientific processes **voluntarily**, either since **they are interested** in science and research or because **they are concerned** about real-world problems. This definition, among others, is essentially referring to a **new type of engagement with science**, which breaks the barriers of traditional ''pure'' science that is characterized by its distinct roles and the monopolistic production of knowledge by professional scientists.

Another official text on CS, the Green Paper on Citizen Science(2013), released the same year and signed by the Digital Science Unit of the European Commission and by Socientize.eu, highlights precisely this dimension **of public engagement in scientific research** processes. By getting involved, citizens can contribute to science and play a role in the production of scientific knowledge, harnessing different tools and methodologies. Thus the **democratization** of science is achieved, since the possibility is opened up for groups and networks of volunteers to perform scientific work and, by collaborating with professional scientists, help to attain common goals. Based on all the above features, CS is an **emerging 'paradigm' of scientific practice**.

Thus, through the engagement of everyday people in scientific research CS **benefits** simultaneously and synergistically:

(a) **science**, since scientific knowledgeis promoted and developed,

(b) **society**, not only by the opening up of the scientific information to the general public, but also by promoting democratic participation, cooperation, responsibility, transparency, consensus and justice for the people, through solving real-world problems, and

(c) **citizens**, since it gives them the opportunity to express their own interests acquire knowledge and cultivate a range of skills.

Specifically, through CS, participants are **''educated''** both as scientists and as citizens, in cultivating a scientific way of thinking and encouraging democratic engagement to deal with complex problems of the modern world, while contributing to the advancement of science as well as developing themselves through this (Ceccaroni et al., 2017).

1.2. How did Citizen Science begin and develop?

Citizen Science (CS) as a specific practice, although not under that name, appears long before the end of the 20th Century. Many people in previous centuries, with no specific scientific training or qualifications, recorded their observations about nature, the world, man and society (Silvertown, 2009). However, the beginnings of the most modern version of CS couldbe traced back to the end of the **19thCentury**, when the term ''scientist'' was coined (1833), replacing such terms as ''savant'', ''philosopher of science'', ''natural philosopher or ''naturalist'', to describe someone who, although usually practising and making a living from some other profession, in their spare time engaged in their **''passion''**, namely research - financed by themselves or by another sponsor.

These first passionate **amateur** scientists pursued the study of various topics, often assisted by others in their personal network who helped them gather and analyse data. A typical example is Darwin, who travelled on the British Royal Navy Ship, ''HMS Beagle'', not as a professional researcher, but as an unpaid collaborator, to study geology, natural history and ethnology. His observations, which he recorded in a diary that was published in 1839 and entitled, "The Voyage of the Beagle", were instrumental in shaping his scientific theory of the evolution of species and natural selection. They established his reputation as a naturalist and made him known as one of the forerunners in the field of ecology, especially in the area of biocommunity issues.

The first **collaboration** initiatives between ''amateur'' and ''professional'' scientists date back to the **end of the 19th- beginning of the 20th century**, following the professionalization of science and establishment of scientific research. However, the high cost of laboratory equipment and, mainly, the rules of conducting experiments in the empirical sciences excluded the general public from the official spaces for the production of scientific knowledge.Similarly, in several fields, the quality, accuracy and validity of the information gathered by the amateur scientists was called into question together with its interpretability.

Immediately after World War II, **education of the population in the sciences** was harnessed not only to raise morale and upgrade citizens' lives, but also to draw attention to a new human potential in the realm of science that would contribute to economic growth and national security while simultaneously boosting prestige during the Cold War (Rudolph, 2000).It enhanced, respectively, the image of science among the general population, making engagement with this field of knowledge self-rewarding.

The 1960's and 1970's were characterized by the social protest movements against the Vietnam War, nuclear weapons, the ecological crisis, the violation of human rights, etc.Amid this climate of opposition **science too came under harsh criticism** as regards how oriented it was towards the real needs of man. **New research approaches**, such as ''participatory action research'' and "community action research" came onto the scene, stressing the need for a **more socially-oriented science** and for a new model ''scientist'' with a civic consciousness and participation in the decision-making processes.

In the 1980's, discourses about the ''knowledge economy'' and ''informational capitalism'' renewed the need for training in more interdisciplinary approaches centred on the basic sciences (Science, Technology, Engineering, Mathematics - STEM) and made **scientific literacy** an essential part of modern citizenship (Kosmin et al., 2008).

In the 1990s, the call for the **democratization of science** and the **opening up of scientific knowledge to society,** combined with the idea of **empowering the citizen** as a basis for a more **democratic governance** gave birth to the ''Citizen Science'' movement and put it in the spotlight. At the same time, ''crowd sourcing", which had started to be discussed in this context at the beginning of the 21stCentury (publication in WIRED magazine: Howe, 2006), further reinforced the whole idea by calling on/inviting the general public to contribute to scientific research and work.

In the last decade, the rise in citizens' average educational level and the increase in their free time, combined with the development of information and communication technologies have accelerated the advances in CS, although in different ways in different parts of the world. In **Europe**, CS is now promoted in universities, research centres, museums and NGOs.The

European Citizen Science Association – ECSA was founded to network the various bodies and the different actions throughout Europe and all over the world.

In some European countries (e.g. Germany, Austria) CS action promotion is supported by government grant schemes. In others, such as Ireland, Australia, Brazil or in Arctic regions, the fact that many of these actions are bottom-up initiatives has shaped also the terms used to reflect precisely this philosophy. In other countries, such as Austria, or Switzerland, the term, ''Citizen Science'' is so recent, or considered so innovative and unusual, that it is not even translated, and its content is adapted to the context and culture of the particular country.

Finally, it is worth noting that CS has been predominantly pursued within the realms of the **natural sciences**, while initiatives linked to **social sciences** and **humanities** are rarer(Heiss & Matthes, 2017). A study by Hecker et al. (2018) showed that more than 80% of the CS programmes examined related to the natural and life sciences and only 11% to social sciences and humanities. Nevertheless, the latter, although less visible and recognisable, seem to be forming a new, very promising area in the field of CS (Tauginienė et al., 2020).

1.3. How are citizens involved in Citizen Science activities and programmes?

There are numerous ways in which citizens can be involved in CS activities and programmes. This depends both on the nature of the CS activity/programme, its theme and the scientific field it comes under or the research questions and methodologies used, as well as on the motivations, interests, skills, scientific expertise, and previous experience of the citizens themselves and their level of participation in the design of the activities/programmes.

Whether as individuals, groups, or communities, citizens can **participate in CS actions and programmes** in many different ways, for example, by:

- *observing or recording species of flora and fauna,*
- *monitoring and contributing to the management of biodiversity and ecosystems,*
- *taking measurements related to environmental quality and public health (e.g. measuring air pollution, noise pollution,odour pollution, temperature, urban greenspace, etc.),*
- *providing personal data relating to physical and mental health indicators (e.g. age, weight, blood pressure, general well-being, attitudes, perceptions), symptoms and epidemiological data,*
- *participating in experimental, clinical trials of drugs and treatment regimes,*
- *copying, categorizing, analysing or annotating information from websites and databases,*

- *testing or building the technological applications themselves,*
- *donating the unused processing power of their PCs to perform calculations etc.*

In most of the above mentioned **practices/ ways of participating in CS,** citizens can implement one or more techniques or methods for data collection and analysis and use online platforms and digital tools (such as mobile phones) or special software. In fact many of these practices can be facilitated, coordinated by, or end up in structures, such as **Citizen Observatories**, which have the appropriate digital infrastructures and offer the relevant services to those participating in their actions.

Bonney et al. (2009) propose another way of distinguishing the type and level of citizen engagement in CS based on **the role that citizens play** in it. It is also useful since it acts as a framework for designing a CS programme. Thus, according toBonney et al. (2009), there are three main **types of CS programmes**:

1. Scientific research programmes, where **the public contributes** to scientific research (contributory projects), without being personally responsible for designing and conducting it. Contributory CS features a top-down approachwhere the initiative and organisation are driven by the (professional) scientists. The role of the volunteer scientists (citizens) is to partly contribute to the programme, primarily to collect data or, in the case of crowd sourcing, analyse data.
2. Scientific research programmes, where **the public has a more participatory role** in conducting the research (collaborative projects). These programmes too are generally designed by the (professional) scientists. However, in this case, the citizens participate in more than one stage of the scientific process (such as data collection and/or analysis, or helping to inform the way in which the questions are addressed or communicating findings, etc.).
3. Scientific research programmes, where **the public co-creates** (co-created projects). This approach envisages scientists and the public (or communities of citizens) working together on the design. In these programmes, at least some of the volunteer amateur scientists (citizens) participants are involved in all steps of the scientific process.

The overall feel of the CS programme and its method of implementation will vary according to which of the above approaches is followed. As will its design. While all the approaches have both **advantages** and **disadvantages**, deciding which is the most appropriate depends on many factors (see Boxes 1 and 2). Of course in reality all CS programmes use a **combination of approaches,** perhaps including a core group of highly involved citizens who help to develop research questions and methods, alongside a wider group of citizens who contribute their observations or collect data.

Citizens contribute…

CS programmes where citizens contribute mainly through recording observations and collecting data have several benefits. For example, they:

• Capture the imagination or align with the particular interests of citizens

• Gather a large volume of observations and data that, through other routes, could not be collected quickly, easily, over a wide geographic area and/or at a low cost

• Allow the recording of regularly, and/or rarely, encountered species or phenomena

• Enable large-scale analyses,that are better done by humans than by computers (e.g. identification of photos of wildlife species or museum specimens).

Source: Tweddleet al. (2012).

Citizens co-create…

CS programmes where citizens collaborate and shape the processes alongside scientists have several benefits such as in cases where:

• volunteering citizens help set up extended environmental quality monitoring systems or record conditions or hazards in an area

• small groups of volunteers collaborate on issues of common interest

• repeated measurements over time are required (and which therefore need a greater commitment from participants)·

• the programmed is targeted at resolving a place-specific environmental problem or question

Source: Tweddle, et al. (2012).

1.4. What are citizens' motivations for participation in Citizen Science?

The people who participate in CS activities may be members of the educational community, i.e. teachers or pupils and students; they may be representatives of professional and scientific associations, or of environmental, nature-lovers and other voluntary bodies and organisations; they may be professionals, such as farmers or fishermen; or they may simply be citizens/amateur scientists, whose professional status and activity may not necessarily be connected to the CS programme in which they are participating, but who are personally motivated, and/or have the appropriate equipment, to make observations and measurements.

In general, the existing literature shows that **citizens participate in CS programmes for a variety of reasons,** the main ones being, according to Raddick et al. (2010), the following: their desire and intention to contribute to science by participating in research, their interest in the research topic, the enjoyment of engaging in research activity, sharing common goals and values, supporting and assisting other people, participating in a group, having their contribution acknowledged, seeking new sources of information and possibilities to learn, developing their creativity, achieving personal goals etc..

After interviewing several volunteers of the "Galaxy Zoo", CS project, Raddick et al. (2010), classified the **motivations** driving ordinary citizens to participate, into the following twelve categories:

- *their interest in contributing to scientific research,*
- *learning,*
- *discovery,*
- *meeting other people with similar interests,*
- *sharing knowledge for educational purposes,*
- *enjoyment of beauty,*
- *fun,*
- *understanding the vast scale of the universe,*
- *being happy to help,*
- *interest in the platform and its subject matter,*
- *interest in the specific scientific discipline (astronomy),or interest in sciences in general.*

Particularly, in the case of CS programmes focussed on environmental issues, such as biodiversity, participant **motivations** appear to

be linked more to an interest in nature and less with society or career (Ganzevoort et al., 2017). Specifically, such actions provide opportunities for: contact with nature and the development of knowledge about nature-related issues; contribution to nature management and conservation, outdoor activity and connection with the place etc. In fact frequent contact with a place, in order to perform measures or take samples, and collaboration with people who share common beliefs and values, strengthen the knowledge and connection with the place, interest and ‘’bonding’’ with the area and cultivate feelings of personal responsibility and pride for their contribution to environmental protection.

On the other hand, the motivations of participants in CS programmes may vary over time(Rotman et al., 2012; Rotman et al., 2014). The reasons that usually motivate citizens to participate in the first place are more personal and internal: the need for personal promotion and social or professional development, curiosity, interest in science and the desire to contribute to research. Later on, however, their reasons for continuing to participate are linked to their interest being sustained, their sense of personal efficacy, and time available. Citizens are interested in participating in another CS programme after the first one when they like the activities involved, when they feel that they have the skills required for the project and when they can devote time to it regularly. Some participate for the first time on a trial basis and then drop out or participate less over time. **Obstacles** to them participating more consistently in such actions arise in cases where citizens find the project dull or difficult or when they cannot devote enough time to it due to their other obligations and priorities. On the contrary, their participation is encouraged and their interest sustained when they become familiar with the project and the other participants, when a team spirit is cultivated and when their effort is recognised. (Jennett et al., 2016).

1.5. What are the principles of Citizen Science?

CS is a scientific research process and, like any other related process, has to follow certain principles. These principles vary according to the research programme concerned, the topic/theme and the scientific discipline it comes under. With these as criteria, the typesand degree of citizen participation, the stages of the research process, the practices, methods and types of data are determined differently. Likewise, different terms are used to refer to the contribution of the citizens involved (e.g. the terms ‘’residents’’, ‘’community members’’, ‘’participants’’, volunteers’’ or ‘’scientists-activists’’).To overcome the obstacles created by the differences between the scientific disciplines Ceccaroni et al. (2017) propose the creation of a single standardised vocabulary and a common methodology for CS.In this way it is assumed that issues of quality control and assurance of the processes will be covered. The European Citizen Science Association - proposes (2016) a framework for good practices for the design and implementation ofCS actions.

1.6. What are the benefits from the development of Citizen Science?

There is a wide range of **expected benefits** from CS action in society, including the following: increased scientific literacy, participatory innovation (Hecker et al., 2018), convergence of research with the policy on sustainability (Petridis et al., 2017; West & Pateman, 2017), transfer of knowledge from one piece of research to another or for use in the personal and collective life of the participants, connection of science with education and the needs of the community, etc. (Tauginienė et al., 2020).

As already mentioned in a previous subsection, CS is **a new paradigm of science**, that changes the way science is perceived and how citizens participate in it. It is a collaborative and two-way process of research, education and action, oriented towards social change. ‘’Expert’’, ‘’accredited’’, ‘’professional’’, academic researchers work together with ‘’non-expert’’, ‘’non-accredited’’, ‘’amateur’’, volunteers, non-academic researchers, to jointly examine a ‘’problem’’ and propose solutions to benefit all interested parties and society as a whole. The ‘’experts’’organize, coordinate and supervise the actions, to which the citizens contribute their ideas, energy or, and often,also their equipment. Naturally, even though this collaboration is based on mutual respect and mutual support, ‘’experts’’ and ‘’non-experts’’ are not considered equal in everything, since they do not have the same resources (background knowledge, time, logistics/infrastructure etc.), nor do they have the same motivations (Haklay, 2015). They are, however, complementary.

CS can empower citizens, groups and communities of citizens, giving them the opportunity to draw attention, through scientific research, to issues that concern them at a local, national or international level. By collecting data and information, leveraging collective and traditional knowledge and expertise, formulating proposals or communicating the results via their social networks, citizens can influence decision-makers or even compel them to take action and formulate policies.Certainly, under no circumstances, must CS be used as a tool for transferring the responsibility for important social functions to individuals (Brown, 2015), nor to make up for the underfunding of scientific research which is afflicting most countries today.

EUROPEAN CITIZEN SCIENCE ASSOCIATION

The 10 principles of Citizen Science

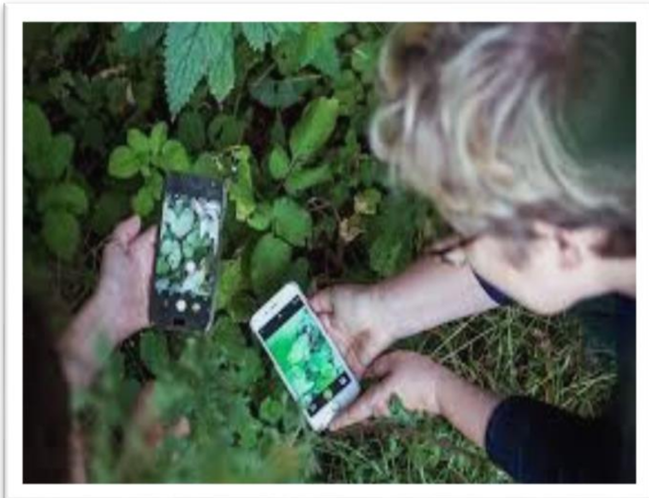
Citizen science is a flexible concept, which can be adapted and applied within diverse situations and disciplines. The statements below were developed by the 'Sharing best practice and building capacity' working group of the European Citizen Science Association, led by the Natural History Museum London with input from many members of the Association, to set out some of the key principles which as a community we believe underlie good practice in citizen science.

1. Citizen science projects actively involve citizens in scientific endeavour that generates new knowledge or understanding. Citizens may act as contributors, collaborators, or as project leader and have a meaningful role in the project.
2. Citizen science projects have a genuine science outcome. For example, answering a research question or informing conservation action, management decisions or environmental policy.
3. Both the professional scientists and the citizen scientists benefit from taking part. Benefits may include the publication of research outputs, learning opportunities, personal enjoyment, social benefits, satisfaction through contributing to scientific evidence e.g. to address local, national and international issues, and through that, the potential to influence policy.
4. Citizen scientists may, if they wish, participate in multiple stages of the scientific process. This may include developing the research question, designing the method, gathering and analysing data, and communicating the results.
5. Citizen scientists receive feedback from the project. For example, how their data are being used and what the research, policy or societal outcomes are.
6. Citizen science is considered a research approach like any other, with limitations and biases that should be considered and controlled for. However unlike traditional research approaches, citizen science provides opportunity for greater public engagement and democratisation of science.
7. Citizen science project data and meta-data are made publicly available and where possible, results are published in an open access format. Data sharing may occur during or after the project, unless there are security or privacy concerns that prevent this.
8. Citizen scientists are acknowledged in project results and publications.
9. Citizen science programmes are evaluated for their scientific output, data quality, participant experience and wider societal or policy impact.
10. The leaders of citizen science projects take into consideration legal and ethical issues surrounding copyright, intellectual property, data sharing agreements, confidentiality, attribution, and the environmental impact of any activities.

April 2016, Milton Keynes, UK

1.7. How is Citizen Science connected to education?

The educational function is a crucial dimension, related goal or product of most of the afore mentioned CS actions and initiatives. As stated by Serrano (2013), in order for people



to understand science better they need to participate in scientific research processes, whereas the production of scientific knowledge itself is by definition associated with learning or should lead to it. Many of the citizens participating in CS programmes have formal qualifications (e.g. academic qualifications, knowledge of foreign languages, technological skills), which are not necessarily connected with the subject matter and methodology of the action they are involved in: they may have very few or no formal qualifications, but many years of experience and involvement in the field, or even neither of the two (formal qualifications or previous experience). They may be self-taught orhave sought to acquire the relevant knowledge through an organized educational programme alongside, or after completing, the activity in which they are taking part. In any case, CS is a new pathway to increasing scientific literacy through the acquisition of new content knowledge and research skills (Jordan et al., 2012).

To date, however, the connection made between CS, education and learning regards mainly the involvement of adults, and this is because they were the main target-population from the outset. CS has been developed very little on the formal education side, compared to non-formal and informal education (such as in museums, interest groups, NGOs, etc.).

Nevertheless, in recent years, it has been increasingly recognized that CS can constitute a dynamic education framework within schools as well, where pupil involvement in relevant activities generates numerous learning benefits. Specifically, Ballard, Dixon & Harris (2017) uphold that the participation of young people in CS actions relating to the natural environment contributes to: raising their environmental awareness, developing their knowledge of ecology, acquiring experience from participation in scientific processes, strengthening their connection with nature and actively involving them within the local community. Interdisciplinary and cross-thematic teaching is also facilitated as is the learning of different subjects/disciplines and through all the above environmental education for sustainability is promoted (Wals, Brody, Dillon & Stevenson, 2014).

To sum up…

In module one of the Training Course an attempt was made to **define** and **delimit** the field of **Citizen Science (CS).**

Specifically, some of the established **definitions** of CS were given, a **historical review** of events that determined its genesis and development to date was provided, different **ways** in which citizens are **involved** in CS practices were presented with reference to the factors **that motivate** citizens to **participate** in CS actions, some of the **benefits** derived from disseminating and implementing it were discussed, the **basic principles** guiding It were outlined,and finally, its relationship with **education** was examined at an introductory level.

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