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Chapter 9
Citizen Observatories as Advanced Learning Environments

Josep M. Mominó
Universitat Oberta de Catalunya (UOC), Spain

Jaume Piera
Institut de Ciències del Mar (ICM-CSIC), Spain

Elena Jurado
1000001 Labs, Spain

ABSTRACT

Citizen Observatories are the technological platforms where a diverse range of tools are developed, such as web portals, smartphone apps, electronic devices, that allow the development of citizen science projects, particularly those with the principal objective of large scale participation of the people, covering large geographical areas and long periods of time. These new observatories integrate the latest Information and Communication Technologies (ICT) to connect the citizens digitally, improve their observational capabilities and provide information flows. The concept of Citizen Observatories offers great possibilities as an educational experience, precisely due to the opportunities offered by the participation of the people, with different levels and roles and therefore, it is assumed in terms of active collaboration of the citizens, in shared processes of knowledge creation. This is especially clear when we pay attention to the complexity of the challenges education must face today, within the framework of a society of knowledge like ours.

WHAT ARE CITIZEN OBSERVATORIES?

Citizen science promotes public participation in the collection of large quantities of observations of a very diverse nature (from the identification of new stars or comets to the detection of cancerous cells and the presence of invasive species, to mention a few examples). These observations provide data in a wide variety of settings and during long periods of time. Citizen science projects have had notable

success in the advancement of scientific knowledge and the contributions of the people are providing large quantities of data in different scientific disciplines. An essential requirement for the functioning of citizen science is the participation of the people, in an extensive and sustained manner. Citizen Observatories are the research infrastructures (i.e. the technological platforms where a diverse range of tools are developed such as web portals, smartphone apps, electronic devices) that allow the development of citizen science projects, particularly those with the principal objective of large scale participation of the people, covering large geographical areas and long periods of time. These new observatories integrate the latest information and communication technologies (ICT) to connect the citizens digitally, improve their observational capabilities and provide information flows.

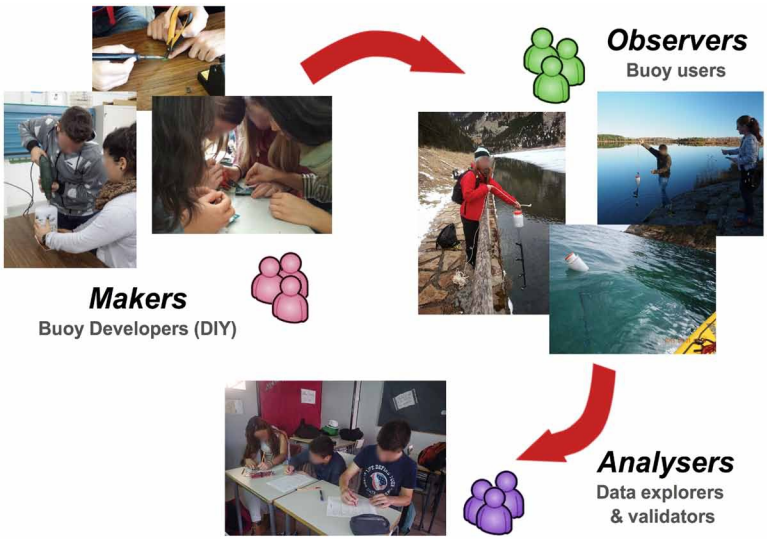
The Citizen Observatories therefore offer an environment where people can participate in citizen science projects. According to an original idea by Arnstein (1969) different levels of participation can be defined, considering to the social and cognitive involvement of the people. In an adaptation of this idea, within the context of citizen science, Haklay (2011) defined the hierarchy of participation with four levels of social and cognitive involvement:

- **Crowdsourcing:** At this level, people generate information passively with little cognitive involvement. For example, people are invited to wear a sensor for a time, after which it is returned to the organisers of the experiment. The information generated is subsequently analysed by specialists in the subjects being studied.
- **Distributed Intelligence:** At this level, the central resources of the project are the cognitive abilities of the people. Most current citizen science projects fall within this level. The people who participate often receive training, which may be in person or using didactic resources accessible on the web. People who can provide information through observations made or through the interpretation of existing information (for example, validating observations made by others).
- **Participative Citizen Science:** This level is characterised by the problem being defined by the community itself. In some cases, it may be derived from an evolution of the projects from the previous level, when the people that have participated have acquired sufficient expertise in the collection and analysis of data, as well as the ability to think up new questions to solve.
- **Collaborative (or Extreme) Citizen Science:** This is the most integrated level where the people participate at all levels. It is not only possible to think up new questions, like at the previous level, but the people can also participate in the design of the methods for acquiring the observations and analysing the information.

Aside from the levels of participation, the Citizen Observatories also offer an environment where the people can collaborate with different roles of participation (see Figure 1):

- **Makers:** These are people with abilities and interests in the technological field. In this role, the people participate by designing new observation instruments and tools, often with low-cost material that is easy to acquire, promoting the concept of *Do-It-Yourself* (DIY).
- **Observers:** These are the people who provide observations, either using existing technology or technology designed by the makers.
- **Analysers:** In this role, the people participate by interpreting or validating existing information. With this analysis it is possible to improve the quality of the information provided by the observers.

Figure 1. ***The roles in Citizen Observatories: An example in the European project CITCLOPS.***
One of the first European Citizen Observatories was developed within the context of the project CITCLOPS (Citizens' Observatory for Coast and Ocean Optical Monitoring).
In this project, the creation of an observatory was promoted to evaluate water quality, using observations provided with the participation of the people measuring simple optical parameters such as the colour, transparency or fluorescence of the water (Wernand, et al. 2012). One of the devices designed to measure water transparency was the KdUINO buoy (Bardaji, et al. 2016). This easy-to-build DIY buoy made it possible to develop the idea of the different roles of participation. People who wanted to participate in the role of Makers could develop their own KdUINO buoy and modify it to improve its features, as the system was developed in a fully open environment (open hardware and software). In the role of Observers, anybody who, due to their frequent contact with the sea (whether leisure or professional activities), would like to take on the installation and maintenance of a KdUINO buoy can participate. The data collected by these buoys is stored in open servers and is accessible anyone interested in using it. It is in this latter context where the role of the Analysers comes into play. The people participating in this role can verify that the data being obtained is correct or can be used (for example in school workshops) to see the differences in the water transparency at different locations and environments of the coast (to ask for example "Is the water transparency different when the coast is rocky or sandy?") or analyse the changes that occur throughout the year in a specific location ("how and why does the water transparency change in the different seasons of the year?").



This concept of science offers great possibilities as an educational experience. This potential for education comes from the opportunities offered by active collaboration of the citizens, with different levels and roles in shared processes of knowledge creation. This is especially clear when we pay attention to the complexity of the challenges education must face today, within the framework of a society of knowledge like ours.

RETHINKING THE EDUCATIONAL SCENARIOS, IN THE SOCIETY OF KNOWLEDGE

We live in a world that is transforming profoundly at a very high speed. The parameters that industrialisation established are being left further and further behind. Our societies are finding new methods of organisation and cultural expression, and new mechanisms of economic production. This reconfigura-

tion, the *network society* (Castells, 2000) builds its structure through information and communication technology (ICT) and is driven by a new form of economy, based on the production of knowledge, with the ability to learn as a primary resource. Innovation and creativity (Florida, 2004), finally, have become the essential fuel for the engine driving this process.

In a globalised world, the governments understand more and more that the dynamics of the economy of knowledge depend more than ever on effective organisation of education (Dale, 2005) that, consequently, must be contemplated as a strategic priority, in order to ensure sustainable growth and social cohesion. The question is that, in the current climate, the dynamics of the organisations and, ultimately, the work of the people is converted, more and more, into the resolution of complex problems with, consequently, the ability to generate and handle information with sophisticated procedures with dexterity when participating in flexible and open structures of collaboration in networks. It also consists of forming relevant questions and learning to resolve them, through forms of systematic reasoning, making use of the enormous potential provided by ICT for the resolution of these processes and, finally, having a high level of initiative, autonomy and critical spirit in decision-making.

The need to find models with the effective ability to form the learners of the new millennium (OECD, 2009) and give them the skills the XXI Century requires (Partnership for the 21st Century Skills, 2005) goes hand in hand with a strong demand for transformation into the distinctive ranges of the traditional education systems. There is a requirement of "rethinking education" (UNESCO, 2015), reconsidering its purpose and knowing how to provide the most appropriate educational scenarios. The need for change refers to the fundamental principles with which it is necessary to design the learning environments (Dumont et al, 2010). The revision must pay attention to what needs to be taught and to the type of skills that must be provided nowadays for a person's integral education. It must also be translated, consequently, into an update of the way they are taught. For this advanced concept of education, finally, education centres have to be able to provide appropriate organisational formulas. This organization should be able to promote and facilitate the development, in their everyday activity, of the teaching formulas and, finally, the learning experiences required by a society like ours.

The measurement of a challenge that considers a change of this type in schools has to be calibrated taking into account the complexity of the factors involved. The education centres gradually change when updating forces them to change the DNA that sustains the way the activity takes place in their classrooms on an everyday basis (Cuban, 1986; 2001; 2012). The traditional concept of teaching practices is structured on a "school grammar" that, in this regard, acts in a similar way to the way it would in language regulation (Hargreaves, 2000; Tyack and Tobin, 1994). The ability to update must always be measured taking into account the significant pitfall that must be overcome to act outside of this "grammar" and leave behind organisational methods and practices that were strongly established in the preceding educational models. Finding the appropriate strategies to make headway in this process of "creative destruction" (Kozma, 2012) often constitutes the main challenge for essential change. Our intention is to show that, within the concept of the citizen science, schools can find an interesting alternative when embarking on this trajectory. The condition is that they are able to approach this concept making the most of the potential of participation in the Citizen Observatories as a new educational scenario. The opportunity isto advance towards a new "ecology of learning" (Barron, 2006; Coll, 2013, 2016) that occurs in different parameters from those that set out traditional teaching practices.

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CITIZEN OBSERVATORIES: AN OPPORTUNITY TO RETHINK EDUCATION FOR SUSTAINABLE DEVELOPMENT

The educational priorities in the political agendas are closely linked to the social, cultural, environmental and economic needs of each era. Industrial society promoted the model of a transmissive and academicist school and established a marked dichotomy between the cognitive, emotional and ethical dimensions in the processes of teaching and learning. The current society of knowledge is facing the challenge of promoting a more holistic model of teaching, with a humanist focus. This perspective is aimed at "Sustaining and enhancing the dignity, capacity and welfare of the human person, in relation to others and to nature" (UNESCO, 2015, 36). From this angle, education can be seen as a process that goes beyond the mere acquisition of knowledge and aims to facilitate the development of skills for life.

The integrated, humanist focus of education that was proposed in the influential report by Delors (1996) conceptualised the purpose of education and the organisation of learning into four fundamental pillars: learning to know, learning to do, learning to be and learning to live together. The same report already underlined that learning to know and, to a lesser extent, learning to do, are the pillars that have traditionally received more attention in formal teaching. The other two types of learning depend more on random circumstances and they are often considered a natural extension of the first two. For an advanced education, however, each one of the four pillars of education must warrant the same consideration so that education is a global experience for the person, providing the integral training necessary to be able to participate actively as responsible citizens in the society of knowledge when faced with the complexity of a globalised world.

Currently, fully immersed in the society of knowledge, in a world that is highly interdependent, interconnected and under pressure, especially in matters of sustainability, these four pillars remain valid, but the need to reinterpret them has arisen. This needs to "rethink education" in accordance with the latest reflection of UNESCO (2015) emphasises sustainability as a worrying concern for global development that has to be incorporated into an integrated, humanist focus of education. The growing concern for sustainability fully affects the reinterpretation of one of the four pillars of the Delors report: learning to live together must go further than the social and cultural dimensions of human interactive, to include a concern for the relationship of society with the natural environment.

The current dominant model of economic development entails the degradation of vital natural resources such as water and the loss of biodiversity. Similarly, the growing superpopulation of cities has consequences for the natural environment, and climate change has brought an increase in natural disasters. It is, therefore, essential to educate citizens to be responsible for economic growth guided by responsible environmental management and social justice. This should be a fundamental aim of education in the 21th century (UNESCO, 2015).

In a context of active concern for sustainable development, Citizen Observatories can provide a valuable educational platform for obtaining life skills. There the citizens have the opportunity to actively participate in the process of scientific research and work for sustainability, collecting, interpreting or analysing data. At the same time, these technological platforms offer a good opportunity to go beyond the traditional concept of the digital divide with a more complex overview about the use of technologies by young people. From this perspective, participation in Citizens Observatories can be understood as

an experience that can contribute to reducing digital inequalities (DiMaggio and Hargittai, 2001). The incorporation of these platforms for educational purposes offers an opportunity to pay attention to the multiple factors that affect the process of appropriation of technology in everyday life of young people. Reviewing the limitations of a simple division between users and non-users (Lenhart & Horrigan, 2003; Steyaert, 2002) allows to adopt a broader view of the social implications of the use of technology (Robinson, DiMaggio, & Hargittai, 2003 ; van Dijk and Hacker 2003; DiMaggio et al. 2004; Warschauer 2003). The incorporation of these platforms allows the school to influence the multiplicity of variables involved in the unequal appropriation of technology (van Dijk, 2005; DiMaggio, Hargittai, Celeste & Shafer, 2004). In this sense, participation in Citizen Observatories can be seen as an opportunity to open a space in the school for compensation of digital inequalities, paying attention to the unequal conditions of access, motivations, abilities, and purposes of use and contribute, from these platforms, to the digital inclusion of young people (Meneses & Mominó, 2010).

Citizen Observatories provide a bridge connecting learners with their environment, promoting active participation. They are also platforms that enable the cultivation of values such as solidarity and shared responsibility for our joint future. From this point of view, it is possible to understand the interest in seeing these observatories as environments for teaching and learning that actively contribute to educating citizens concerned about sustainable development, competent in using tools to characterise the current situation of the ecosystems and their future evolution, and able to collaborate with other learners and with entities involved in knowledge generation.

CITIZEN OBSERVATORIES: A PLATFORM FOR AN ADVANCED CONCEPT OF TEACHING AND LEARNING

The concept of citizen science to which we refer offers favourable ground when promoting this humanist vision of education. This conception of science enables connections to be made with a holistic representation of education in which knowledge is understood as a joint process and the people who participate in this collective construction can learn bringing significance to the experience, processing information and recombining it, but above all deepening understanding and, at the same time, developing skills, and acquiring attitudes and values. The Citizen Observatories can offer a platform for the generation of this integrated way of understanding knowledge. Those who contribute can learn to use it, collaborating from diverse positions, developing the necessary skills to apply this knowledge in complex contexts, such as those provided by the citizen science project, to respond to specific, relevant demands.

Anyway, the ability of the Citizen Observatories to provide an advanced environment for learning does not depend solely on the potential we have just mentioned. The result of the educational experiences carried out with these platforms ultimately depend on the ability to guide the participation of the different parties involved taking into account the knowledge accumulated on the way people learn. For this reason, the pedagogic design of the activity carried out in these observatories, within the framework of the citizen science project, ends up being fundamental. The research by the OECD (2010) on the nature of learning synthesised some of the principles that, from this point of view, should enable support for the configuration and dynamics of learning environments in the XXI Century. The revision of these principles, applied to Citizen Observatories, must allow us to rethink the structure and functioning of these platforms, with the aim of getting maximum effectiveness in educational terms from them.

Citizen Observatories as Advanced Learning Environments

- *Citizen Observatories: A Learning Experience with the Students in the Lead Role*

The socio-constructivist concept (Bransford et al., 2006) that, today, prevails when interpreting how learning occurs reveals that in this construction process, nobody can replace the learner. Therefore, the students have to be at the centre of these platforms, it must be possible to find the possibility of being actively involved in projects that connect with their interests, stimulating their commitment and promoting the active exploration of knowledge. Appropriate activity design, in the observatories, must be able to offer the opportunity to develop metacognitive habits, related to the processing of information, and the analysis, evaluation and diffusion of knowledge. It must facilitate the acquisition of mechanisms for establishing and monitoring personal objectives linked to the project in which they are participating, for their own time management and organisational ability. Ultimately, the Citizen Observatories have to provide an environment that provides the gradual growth of the students' ability to self-regulate and, in short, their autonomy.

- *Citizen Observatories: A Space for Learning through Cooperation*

This is especially valuable when we take into account that, from the same socio-constructivist concept to which we have referred and in keeping with the contributions of neuroscience in particular, we can underline the fact that learning is a shared construction process that occurs through social interaction. Thus, the fact that participation, through different levels of social and cognitive implication, as we have highlighted in the first section of this chapter, is a defining aspect of these observatories is a fundamental factor for the construction of these platforms as an advanced learning environment. The effectiveness of cooperative work, however, with regard to obtaining knowledge, but also on a level of behaviour, emotions and development of values, ends up depending on the pedagogic design of the activity. The dynamics of cooperative work has to be well-organised in order to provide learning opportunities for all of the students, establishing not only group, but also individual, objectives and evaluating them.

- *Citizen Observatories: Motivation and Emotions in Generating Knowledge*

This is essential for learning (Pekrun et al., 2007). The experience of participating in citizen science is a magnificent opportunity for young people when identifying the relevance of what they want to learn. This is especially valuable in an environment such as sciences in which, all too often, schools find themselves with difficulties connecting the activity that takes place in the classroom with life skills. Participation in Citizen Observatories helps the students to make sense of their learning, connected to specific purposes of participation in citizen science. The real value that young people can attribute to the data collected and the perception of their effective contribution to the body of knowledge facilitates the interaction between motivation, cognition and emotion that ends up being critical for the quality of the learning.

- *Citizen Observatories: A Space Open to Participation of All Students*

The individual differences that we find in the classrooms are very important and cannot be ignored when the aim is learning that can be significant for all students, not just a few. Young people do not only have different interests and motivations, they also start with diverse prior knowledge, skills and even

cultural contexts. Participation in citizen science projects, however, allow on one hand different levels of participation that, as we have seen, provide different levels of social and cognitive implication. On the other hand, participation in these observatories also enables those involved to adopt alternative roles for collaboration, able to adapt to the differences to which we refer. From this point of view, versatility is another of the Citizen Observatories' strengths as a learning environment.

- *Citizen Observatories: A Challenge for Each Student.*

The range of options that can be provided by these platforms, when attending to the differences we have just mentioned, also have to be able to be deployed in the form of diverse challenges. Each goal should be adapted to the characteristics of each student, linked to their interests and thus, finally, stimulating their implication and personal commitment when achieving their own objectives. The potential of the Citizen Observatories must also be seen from this point of view. It is about paying attention to the flexibility that these environments can provide when setting appropriate milestones for each student that allows them to gradually self-regulate their participation and gain a degree of personal autonomy in a motivating, and at the same time demanding, context of collaboration with classmates and supervision by the teachers.

- *Citizen Observatories: A Process of Ongoing Assessment*

The quality of the activity carried out at these observatories is closely linked to the assessment mechanisms incorporated. In this regard, the teaching staff's role is fundamental. Beyond the definition of the objectives and expectations for each student, as we have just mentioned, the contribution of the teachers providing feedback at all stages of this project is fundamental in two ways. On one hand, feedback on the activity of each student must provide an essential formative feedback to be able to gradually adapt their actions, gain autonomy and develop the skills necessary to contribute to the activity of the observatories more and more efficiently. On the other hand, this ongoing assessment process that must be carried out by the teachers must also result in a review of the observatory's activity as a whole. The assessment of this dynamic must allow the design to be adjusted in such a way that provides better performance in terms the learning results and, at the same time, quality in the contribution of the observatory to the citizen science project.

- *Citizen Observatories: A Permeable Environment*

Finally, we must bear in mind that the activity of the Citizen Observatories, by their very nature, cannot be developed in a closed environment. The very concept of citizen science, based on ideas of extensive, large-scale participation, advocates forms of activity based on collaboration in a network of diverse participants with different roles and even geographical locations. Thus, the incorporation of Citizen Observatories into school activity can effectively contribute to the promotion of schools. This is a fundamental challenge for some institutions that, all too often, have functioned as a closed site, if they aim to offer education able to respond to the challenges that arise in the knowledge society, in a globalised world. Furthermore, the ability to be open that Observatories can also bring must be able to be contemplated in an internal sense, paying attention to the opportunities offered by participation in the citizen science projects for the horizontal connectivity between diverse areas of knowledge. Understanding

that the ability to establish this type of transverse connections helps to develop more profound forms of knowledge enables the potential of Citizen Observatories as a learning environment to be seen once more.

Ultimately, it is important to note that it is the combination of these principles, more than the emphasis on one of them, that gives these learning environments their power (OECD, 2010, 2012). Similarly, when setting them in motion, Citizen Observatories can be used from different pedagogic focuses. Let's look at some:

CITIZEN OBSERVATORIES: AN OPPORTUNITY FOR LEARNING BASED ON RESEARCH

Research-based learning occurs when the learners participate in projects using methods inherent in scientific research. Thus, the learners question, investigate, consider hypotheses, test, analyse and communicate. This type of research-based project provides the opportunity to participate in real-world situations, which has shown its positive effect in terms of depth and meaning of the learning that can be obtained (Barron & Darling Hammond, 2012). Citizen Observatories have the potential to provide environmental data from the users, which can benefit the sustainability of their environment. This data, duly filtered, can provide decisive information for the construction of models that may allow the evolution of ecosystems to be predicted. Thus the users of the Citizen Observatories can feel empowered through their participation in the fabric of scientific research and, to a certain extent, of environmental government.

Ideally, and with the attentive guidance of an educator, the learners learn to consider questions and projects that are relevant to them. The result may be learner-based learning that can take into account the individual differences, as the design of these projects can contemplate the possibility of participation respecting different paces and different methods and paying attention to different contents. The active intervention in this type of authentic experiences provides better opportunities for more in-depth and meaningful learning due to the importance that young people may attribute to these processes and the involvement they get out of them, in emotional and motivational terms. In this regard, the participation in Citizen Observatories as a research-based learning experience brings into play the principles that come together in the nature of learning (OECD, 2010).

Participation in citizen science projects, through these Observatories, with a research-based learning focus, provides a magnificent opportunity for the development very diverse skills, including independence, creativity, critical thinking, communication, collaboration and persistence when faced with uncertainty (Dumont et al., 2010). Research-based learning, similarly, requires students to know how to develop the skills to filter and discriminate an avalanche of often unreliable information that can be accessed on the Internet. It is important to bear in mind that all of these types of learning can be incorporated into what we have come to call XXI Century skills (Partnership for the 21st Century Skills, 2005). From this perspective, research-based learning enables the students to perceive the creation of knowledge as an open process that is not only in the hands of the teachers, but also that it is built collectively and acquired throughout life in diverse situations.

Citizen Observatories, when conceived as environments for research-based learning, incorporate mechanisms for cooperation and have ICT tools that enable communications within the framework of the centre where they are located, but also beyond their limits. Thus collaboration between learners is sought, but also with various other parties involved, linked to research, paying attention, specifically, to the social nature of learning and the process of knowledge generation. In the same way, this type of

environment must provide a high potential for the development of strategies of systematic work and analysis, of metacognitive skills over the learning process itself, but also for creativity. In short, the participation in research-based environments allow the deployment of in-depth forms of reasoning that give young people the opportunity to develop higher-level skills in knowledge generation.

This is how, in schools, with resources and an appropriate pedagogic design, Citizen Observatories can provide suitable environments for developing research-based learning. The strength of the observatory as a learning environment is built with a sufficient degree of structuring, with suitable mechanisms for support and guidance for the research and analysis, able to guarantee desirable results and ambitious products. The design and development of these environments require a high level of involvement, the ability to manage resources and, principally, educational evaluation instruments able to identify the range of skills set into motion in these research-based environments, aiming to go further than what can be grasped using traditional evaluation systems. In this regards, another fundamental factor for the correct functioning of these experiences comes to light: the teaching staff who must design and promote these environments must have the necessary training to be able to achieve the best yield in educational terms.

CITIZEN OBSERVATORIES AS A LEARNING ECOSYSTEM

Immersed as we are in the society of knowledge, the new economic and social stage has brought with it a paradigm shift in the way people learn. Many of the factors on which learning processes have traditionally been based are gradually becoming blurred. The time and place we learn, how we act during this process, the parties involved that we interact with, and even what we learn and the purpose we give to learning has taken on a new configuration. It is more and more palpable that learning occurs and will occur throughout life, but also that it extends, in a transverse sense, across the breadth of life, in new learning scenarios that are ever more modelled by digital ICT. This technology and in particular mobile technology such as smartphones, laptops and tablets with wireless connections are playing a decisive role in the definition of new contexts of activity that provide new opportunities and resources when learning. ICT plays a role in both in the support of new niches of learning and in the reinforcement of the more tradition contexts of learning and, ultimately, they are paying a decisive role in the mediation of the learning process itself. All of these substantial modifications situate us in what some authors have called a new ecology of learning (Barron, 2006; Coll, 2013)

These great lines of change in the way people learn require new interconnections between parties involved in education, new ways to adapt to the new configuration of the ecosystem of learning. Before the complex challenge schools must face in these circumstances, Citizen Observatories can provide the types of educational experience, in line with the paradigm shift to which we are referring and, in this way, they can provide learning environments able to respond to the education challenges posed by the society of knowledge. Citizen Observatories are built on technological platforms, through vertical spaces, making use of mobile technology. Thus, they redefine the possibility of collaborating with the community and cultural or leisure institutions for learning through a process of shared knowledge construction. It is in this regard that these Observatories, accommodated in or closely linked to schools, may be especially relevant within the contemporary context of reconsidering the interconnections of schools with their environment. At a time when many schools still base their educational model on the traditional dynamic classroom-centred and teacher-student knowledge acquisition, there is a need for distributed educational models able to contemplate the extent of the network of learning contexts through which the students

will pass and integrate others into non-traditional learning environments. This change of focus responds to the vision of education as ongoing, where formal education centres can interact more closely with other, less formal, educational experiences. This opening in the network allows schools to get the best out of their social and cultural capital with a more permeable position to network collaboration.

Furthermore, in a scenario like this, in which people are faced with learning needs in more and more diverse moments and contexts, the acquisition of the types of skills that enable learning in this diversity of situations has special importance. Citizen Observatories, in this regard, can offer a favourable platform for the acquisition of this type of skills, stimulating the ongoing learning of the students and, at the same time, other essential capabilities such as creativity, critical thinking, independence and persistence, among others. In these spaces, more than the product created, attention should be directed at the process and the skills required for the creation of engines for obtaining environmental data or for the observation or analysis of this data. Furthermore, participation in the Observatories through different learner profiles (makers, observers and analysers) provides the opportunity for everyone to go a step further in their learning paths, according to their own pace and trajectory. The confluence of these learning principles in the participation of the Observatories in the learning ecosystems again show the contribution they can make for the configuration of advanced learning environments.

The possibility of participating in the Observatories through diverse profiles makes it possible to connect with another of the effects of the modifications of the learning ecosystem to which we refer: the diversification of the learning trajectories adhering to the ever wider range of contexts and experiences that people go through in their learning trajectory. The needs to recognise these individual trajectories and rethink the personalisation of this learning (Coll, 2013) is a significant challenge for formal education institutions. When moving the focus of attention towards this diversity of trajectories, Citizen Observatories can again provide an appropriate platform, to the extent that through their design the emphasis is also placed on knowing how to accompany, in personalised manner, diverse itineraries and ways of participation to educate competent people, able to learn to learn in an ubiquitous manner, from different situations and positions. From this perspective, schools have to be able to maintain their central role, interconnecting the learning contexts through which the individual students pass.

Also from this point of view it can be understood how it is important to properly integrate Citizen Observatories into schools, through appropriate collaboration formulas. This process of integration does not happen easily; it requires an effort in the design, organisation and management. In contrast, it is easy for the Observatories to end up acting as independent centres, with an autonomous dynamic disconnected from the everyday activity of the centre as a whole. In this case, we have an annex that provides little added value to the school. The potential of Observatories, in these circumstances, is wasted. To boost the interconnections necessary, it is important that the projects carried out are interdisciplinary and favour transverse connections with the content of the curriculum in the different areas of knowledge. For this reason, the education centres need to be organised with sufficient versatility, able to approach these Observatories properly to promote good use for an advanced concept of the educational processes. The participation of the teaching staff in this process is fundamental and requires and education that allows them to properly guide the activity of these environments with educational purposes. Fundamental guidance is necessary when promoting the investigative spirit and research skills in these spaces. Ultimately, the pedagogic design of this process also has to incorporate appropriate education evaluation methods that reveal and contribute to the development of the whole range of skills that the Observatories put into motion, monitoring the activity as a whole to readjust it and appropriately redirect the individual learning trajectories.

It is in this case that Citizen Observatories can provide an educational experience adapted to the new ecology of learning, able to be deployed beyond the walls of the school, through projects that capture the interest of the students with problems that are relevant to their surroundings.

CITIZEN OBSERVATORIES: AN OPPORTUNITY FOR LEARNING AND SERVICE

In a world where technification, urbanisation and, in general terms, the models of economic consumption and production are helping to distance citizens from their environment, weakening the institutions before the large economic corporations, the purpose of education must be to guide towards the value of sustainable human and social development once more (UNESCO, 2015). As a response to the ecological tension, it reveals the importance of responsible action of the people towards the environment and active participation of young people in projects that improve the social, economic and environmental conditions of their surroundings. Projects working towards sustainability are especially important, in circumstances like those we are experiencing in which the degradation of natural resources is a fact and environmental awareness is a necessity. In this regard, it is essential to educate powerful citizens with an active role in environmental governance.

The projects of learning and services are designed so that learners undertake actions for the good of the community, using knowledge to participate in authentic situations and complex social problems. These projects can entail a wide range of social questions (environmental, health, human needs, multicultural issues, etc.), and a service of direct action in the community or indirect action (performing a study to improve a community problem, for example). It is however a requirement that in this type of projects there is equilibrium between learning academic knowledge and serving the community. If it were only a case of undertaking projects for the good of the community it would be more voluntary work than learning and service that should benefit both participants and end-users.

In participating in projects of learning and service, the students are involved in the problems of their surroundings. The community gives them the magnificent opportunity to participate in authentic learning situations that allow them to put into motion their skills, to design and apply solutions to real-life problems, linked to the immediate context or to society in a more general sense. Participation in these projects often results in greater empowerment and awareness of the possibilities of active participation in social problems and, definitively, a greater degree of commitment in civic and political matters (OECD, 2015).

Beyond what it contributes through the acquisition of these values, participation in this type of projects, with the appropriate design, can also lead to the confluence of the principles involved in significant learning. The students must find the opportunity to leave behind their traditional role of passive receiver to adopt a leading role as a creator, designer and active supplier of specific actions (Cairn and Kielsmeier, 1991) that can be as relevant for the community as for the students themselves. With this socioconstructivist concept, knowledge is constructed or reconstructed by the subject itself that learns through the action and social interaction, in a building process shared and guided by the teaching staff. In keeping with the significant range of skills that these processes put into motion, it is not unexpected that, currently, participation in initiatives of learning and service are gaining weight in education systems all over the world, in both the context of the OECD and beyond (Furco, 2010).

Experiences of learning and service can be generated through very diverse disciplines. They can incorporate students at very different educational levels and can be linked to a wide range of social questions, including sustainability and environmental tensions, without doubt, a challenge for participation from an

educational setting. Citizen Observatories, from this point of view, can offer a valuable alternative when responding to this challenge. Participation in citizen science projects allows the Observatories to adopt this concept of learning and service and, from these platforms, design learning environments in which school activities can be linked to specific social problems, for example those related to maintaining the balance of aquatic ecosystems to which we referred to previously. In this case, it is about participating in the evaluation of the problems that threaten them, such as pollution or overuse of resources, and that impact the measures that can be carried out in order to develop more sustainable activities.

The link of the Observatories to this type of project generates a type of activity that must be deployed transversally, through different disciplines. The interaction that occurs in these environments, when linked to authentic problems that have real consequences for the community and for the complexity inherent in these situations, must be possible to expand beyond the limits of the education centres. Thus it has been possible to establish links for collaboration with diverse entities and parties involved, through various types of networks, for the configuration of which ICT is an essential ally. Participating in these processes, students can deepen their knowledge, discovering the link between concepts and procedures in diverse areas of knowledge and, same time, they can develop attitudes and values of civic commitment, regarding problems that affect the dynamics of daily life in their surroundings. Participation in these projects makes it possible for learning to occur, making sense of the experience, in a process in which the link between the cognitive and emotional aspects are particularly highlighted.

The adoption of Citizen Observatories in education centres for the development of learning and services projects can incorporate the guidance of the teaching staff, necessary for the design of the learning environment, for the correct implementation of the project and, in short, to be able to get the most out of it in terms of education and community service. For this reason, however, it is fundamental for the teaching staff to be able to design and apply the appropriate evaluation mechanisms to measure the learning that participation in these projects allows us to contemplate in its holistic sense. Ultimately, the possible performance of Citizen Observatories, linked to this type of project, also depends on the flexibility of their internal organisation for interdisciplinary collaboration and, at the same time, on the ability to open up education centres for collaboration with the environment and making the most of its social and cultural capital.

CITIZEN OBSERVATORIES: A PROPOSAL FOR COOPERATIVE LEARNING

As sustained, extensive participation is a fundamental component of citizen science and taking into account that this participation in Citizen Observatories is classified into different levels and possibilities of the social and cognitive involvement of the participants, it is important to pay attention to the possibilities provided, in educational terms, by this dynamic of collaboration that is consubstantial to these projects. Primarily, it is important to note that the possibilities of interaction between people and the group work of the different parties involved, in themselves, do not entail any benefit in educational terms. The characteristics taken on by this working dynamic directly affect the quality of the results in terms of learning. In this regard, solid evidence enables us to ensure that these positive results are only obtained in certain circumstances that, only when they occur, allow us to speak of “cooperative work”. In fact, the knowledge available (Slavin, 2010) on the effective contribution of this form of collaboration in the construction of knowledge, but also for motivation and social cohesion, does not correspond sufficiently, in general terms, with the level of implementation it has in the everyday activity of education

centres. Participation in Citizen Observatories provides a magnificent opportunity to benefit from the possibilities of collaboration between the different participants, if this working dynamic is designed and implemented effectively in terms of cooperation.

Thus it is important to understand that participation in citizen science projects, through the different levels possible (Arnstein, 1969), requires the activity to be correctly designed so that it properly guides the interaction of the different parties involved, taking into account their different roles: makers, observers or analysers. The responsibility of the teaching staff is fundamental in this regard, when achieving effective collaboration of students in cooperative terms. For this purpose, it is essential for the activity to be considered so that each of the participants has to be aware that the result of their own work is important, but no more so than that of the rest of their colleagues with whom collaboration is established (Webb, 2008). In this sense, the activity must be designed and guided by the teaching staff in such a way that the objective cannot be deemed completed simply by having completed a certain joint observation task. The aim must also refer to what the team is able to learn together. Thus the success of the team must be linked to the result obtained by the group as a whole, and also what each of the members has learned. The design of the evaluation tools that adequately contemplate this double aspect is a necessary mechanism to guarantee the functioning of cooperation in the Observatories, the performance of the collaborators and, ultimately, the quality of the contribution to the citizen science projects.

Furthermore, it is also important to bear in mind that cooperative work is only effective when all members of the teams can find opportunities to collaborate. The activity design must contemplate this requirement and make the most of the different roles from which it is possible to participate in the Observatories to attend to the individual differences. With appropriate guidance by the teaching staff, in keeping with their interests and learning style, each one can find their place as makers, observers and analysers and interact in an interdependent manner. The methodology of the cooperative working established by the teaching staff has to set clear and ambitious objectives and for the teams, as well as personalised objectives for each of the participants, in keeping with their different roles. Ultimately, to guarantee effective cooperation, the evaluation criteria must establish that the success of the team collaborating with the Observatory depends on the individual learning of each of the participants.

Cooperation, furthermore, should not only be established among diverse roles, the activity of the Observatories must also be able to be designed so that the work of those who collaborate within the same role is also carried out in collaboration. In the case of makers, for example, their cooperation must occur in the process of designing new observations tools and instruments. The teaching staff will have to facilitate cooperation in keeping with the interests, often of a technological nature, of these makers. Their guidance must consist of promoting, on one hand, the concept of *Do-It-Yourself (DIY)*, providing autonomy, self-regulation and entrepreneurship for each person. At the same time, however, the teaching staff must also ensure the cooperation is able to lead to a veritable process of co-creation. With a well-defined work strategy and the appropriate evaluation instruments, Citizen Observatories can offer cooperative environments in which *do-it-yourself* (DIY) can give way to *do-it-together* (DIT) (Hagel, Brown, & Davison, 2010).

The opportunities that Citizen Observatories provide as an environment of cooperative working are not reduced to the dynamic established within the framework of the education centre itself; cooperation can also extend beyond the limits of the school. The information generated from the technological platforms in the Observatories are disseminated via the Internet and is used by other Observatories. Thus, collaboration can be established between different education centres and, similarly, with other types of public or private institutions that, with a well-designed work strategy, can participate in effective processes of cooperation in networks. Thus different Citizen Observatories and different schools can learn together,

acting collaboratively in joint projects and establishing effective links in terms of social cohesion. This extensive, complex concept of cooperation that allows participation in Citizen Observatories constitutes another aspect of these environments that enable us to harness the potential to obtain the type of skills needed in a society as complex, interconnected and interdependent as ours.

CITIZEN OBSERVATORIES: LEARNING WITH TECHNOLOGY

Citizen Observatories, by definition, incorporate a wide range of diverse technology types that enable us to improve the skills of the participants, in both acquisition and transmission of information. One of these general objectives, shared by all citizen science projects, is that both quantity and the quality of the observations reported by the citizen scientists gradually improve. There is an intrinsic interest in the people participating acquiring, over time, better abilities in the process of obtaining information needed. The technology linked to Citizen Observatories therefore contributes to the creative learning environments from which the Observatory itself benefits, as the people participating in the project become more expert.

It is necessary to analyse, therefore, the different technology that can be used in the educational processes, within the context of the observatories. In studies carried out previously to evaluate the various technological options for learning, Graesser and colleagues (Graesser et al., 2008; Graesser & King, 2008) suggest ten genres of technology-based learning environments, which we will analyse below within the context of Citizen Observatories:

- **Computer-Based Training:** In this case, learning occurs through classes, experiments and comments presented on a computer screen. This is often done in a format of progressive learning in which the student moves on to the next section after passing a test verifying that the knowledge presented in the current section has been assimilated.
- **Multimedia:** In this field, training is given through images (for example, illustrations, photographs, animation and/or video) and words (such as printed or spoken text). This format enables information of a certain complexity to be transmitted in a format that facilitates understanding. It can be very useful in the context of the Citizen Observatories, for example, to explain to the participants with the role of *Makers* the different steps to build a DIY instrument using videos that explain the process. It can also be useful in other roles: images and explanations on how to distinguish, for example, a species of interest, in the case of the *Observers*, or how to validate an observation or apply an analysis method, in the case of the role of *Analysers*.
- **Interactive Simulation:** In this type of simulation, the student has some degree of control for example establishing input parameters and observing what happens. It may be of special interest in the case of the *Analysers* who can present predictions regarding the variation of the results in different user-controlled, simulated scenarios.
- **Hypertext and Hypermedia:** In this field, the educational material is presented in a format with which the student can have a certain control over the flow of information, navigating through links and references.
- **Smart Tutorials** *:* These learning systems monitor the knowledge of the student and adapt the contents presented in accordance with the results. With this system, the diversity of knowledge between the students is taken into account, so the training is made more flexible and adapted according to the degree of expertise of the users.

- **Obtaining Information Through Searches:** This is currently one of the most widely used systems for accessing new sources of information, in an environment as dynamic as the web.
- **Animated Teaching Agents:** In this case, characters are implemented that appear on the screen and help guide the student through a computer-based lesson. In the context of Citizen Observatories, these characters can be designed related to the target topic of study.
- **Virtual Environments with Agents** *:* In general, these are realistic environments that simulate interaction with real characters, often using natural language. Sklar and Richards (2010) identify three types of agents in virtual environments:
  - *Pedagogic agents*, that are often presented as narrators that offer voice-over explanations without appearing in the scene and that are activated when the students (directly or indirectly) indicate they need help.
  - *Peer-learning agents* that are presented and interact with the students as if they were classmates, tutors or instructors.
  - *Demonstrative agents*, very different to the other two types, these agents are used above all in the context of learning by doing, one of the contexts most used by *Makers*.

For example, demonstrative agents allow the students to program using simple commands and verifying graphically, at that moment, the effects of their code. This does not only allow the students to learn the concepts of programming, but it also provides them with lessons of a wide-reaching scope in process modelling.

- **Serious Games:** This term is used to define games aimed at incorporating an educational function. Bowser, Hansen and Preece (2013) reviewed the different options of gamification in citizen science projects, signalling the potential of games in both learning and complementary systems to increase participation.
- **Learning Supported by Collaboration Technology:** In this field, the groups of students work together on a task communicating through computers. This is one of the fields that enables the integration of activities developed for the different roles (*Makers*, *Observers* and *Analysers*) that participate in the observatories. It is in this environment where it is possible to develop the new concept of Collaborative Science of *Do-It-Together* (DIT) (Hagel, Brown, & Davison, 2010) integrating the expertise of each one of the roles.

Despite the range of tools that can favour educational processes in the context of Citizen Observatories, it is important to bear in mind some of the barriers and challenges that can affect some of these learning processes.

On one hand, the motivation and preparation of the students. There is a growing concern regarding the preparation of enough students, teachers and professionals in the areas of technology, engineering and mathematics (STEM) (Fairweather, 2008; Osborne & Dillon, 2008). A large majority of secondary school students do not manage to achieve the skills in mathematics and science, in a context in which these subjects are often given by teaching staff who do not have sufficiently up to date knowledge to teach these disciplines.

On the other hand, it is important to bear in mind the fact that the ability to participate actively in technological activities requires time, knowledge and the economic resources to access or purchase equipment, etc. These aspects can mean that some people are excluded due to a lack of confidence in

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their skills, in the educational models or in the resources available. These potential problems, however, can be considered a challenge to change in the future. Citizen Observatories can constitute innovative platforms that act as catalysts and favour the incorporation of the transverse principles that must guide the creation of the learning environments of the XXI Century.

CITIZEN OBSERVATORIES: THE CHALLENGE OF RENEWING EVERYDAY EDUCATION PRACTICES

Ultimately, however, it would be naïve to wait for our expectations of the enormous potential of Citizen Observatories, as an environment for the development of the skills required by the XXI Century to give results through the mere incorporation of these platforms into primary and secondary schools. Demanding that impact, as if it were a switch that could be activated in any circumstances, can only be based on an absolute lack of knowledge of the functional dynamics of education centres and teaching itself. In reality, making use of all that these observatories can provide, in terms of the effectiveness of the education action and finally the improvement in the nature of the learning that the students can obtain, is almost never a straightforward process. The difficulty lies in the complexity that, all too often, education centres find in adapting themselves to these Observatories with an advanced vision of what the school has to teach and the young people have to learn in this society of knowledge.

Thus, the effect Citizen Observatories can have on the everyday activity of schools must be linked to their ability to deploy education centres when building an appropriate context for the parameters in which the educational action must be situated within a society such as ours. The construction of this space, without doubt, requires more and more flexible structures with an open capacity for collaboration in networks in projects with a variable extent and configuration, such as those generated around the Citizen Observatories. Similarly, it requires greater opportunities for the initiative and creativity of all the participants: students, teaching staff and other parties involved, whatever their role level of participation. The challenge consists of knowing how to link collaboration in citizen science projects with of holistic concept of education, able to break the dichotomy between cognitive, emotional and ethical aspects. It is therefore about promoting scenarios where the students can put into motion the skills they need for life, participating in situations that may be relevant, such as those these projects can offer.

Subordinating the organisation of schools to this concept of educational aims is a complex undertaking. Generating the conditions that must enable the promotion of advanced learning environments such as those that can be generated from the Citizen Observatories have into account at least three conditions of possibility (OECD, 2015):

1. **Formulas of School Organisation at the Service of the Nature of Learning:** It would not make sense for this adaptation to occur the other way around, even though in reality in the case of schools this logic is contradicted all too frequently. The organisational formulas of the education centres must be subordinate to the needs considered by the design, development and, let's not forget, sustainability and, therefore, the continuity of the learning experiences proposed by the participation in Citizen Observatories. It is about rethinking the dynamics between the core elements of teaching practices to optimise them according to the knowledge available, incorporating advanced formulas for a formative evaluation of the skills in play, versatile formulas for the organisation of

the teaching staff and students, more flexible structures for the use of space and time that facilitate the establishment of the necessary transverse connections for solid learning.

2. **Leadership for Learning:** Promoting the development of these advanced environments requires forms of leadership (Pont et al., 2008) with a high level of commitment to facilitate the best conditions possible for the learning of all the students. Thus, the effective incorporation of citizen science projects into schools also depends on ability of the education centres when developing this vision. This capacity should, ultimately, result in the deployment of the strategies necessary to advance towards schools, conceived as learning organisations (Senge, 2006). In this case, the centres have a shared vision of the teaching staff as a whole and a high capacity for teamwork when designing and sustaining the dynamics of advanced learning environments such as those that can be developed from the Citizen Observatories.
3. **Schools as Open Organisations:** Schools often carry out their activity with limited contact with their environment. This closed position has led to a certain separation between the activity occurring in the classrooms and the everyday life of the young people outside of school. In the network society, however, the spatial limits of educational activity are gradually being blurred (Davidson & Goldberg, 2010). In the new social order, the distinction between those who have the knowledge, those who generate it and those who transmit it are harder and harder to perceive. A profusion of diverse players build their artefacts and cultural products into the network. This context offers great opportunities for schools to access a significant range of environments and learning resources and also for the possibility of collaborating with diverse institutions and players The challenge of schools and their professionals is to reverse their traditional position of closure, know how to decode the potential of the environment and the players to generate different collaboration projects that can result in the improvement of the education quality. In this regard, it is necessary to understand collaboration in Citizen Observatories as a magnificent opportunity to use and expand their social, cultural and professional capital through collaboration with the diverse parties involved and institutions linked to these projects.

Schools need to know how to meet these challenges, not just to be able to harness the enormous potential that Citizen Observatories provide as a learning environment, but also to be able to properly position itself as an organisation able to respond to the challenges posed by education in the XXI Century and, at the same time, able to offer a reference that may still be valid for young people, within the framework of the society of knowledge.

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