Co-designed Citizen Observatories Services for the EOS-Cloud

H2020 programme: Research and Innovation action

Deliverable 6.2 Guidelines on Best Practice for Citizen Observatories (COs) as part of the Cos4Cloud Outreach Methodology Report

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R	Document, report excluding the periodic and final reports	X
DEM	Demonstrator, pilot, prototype, plan designs	
DEC	Websites, patents filing, press & media actions, videos, photos, etc.	
SOF	Software, technical diagramme, etc.	
OTHER	Flyers, etc.	

Dissemination level		
PU	Public, fully open	X
CO	Confidential, restricted under conditions set out in Model Grant Agreement	
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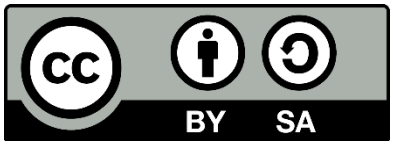

Executive Summary

Co-designed Citizen Observatories Services for the European Open Science Cloud (Cos4Cloud, (https://cos4cloud-eosc.eu/) is developing thirteen technological services focused on boosting citizen science observatories to help increase and improve the quantity and quality of observations.

Cos4Cloud includes the participation of nine established citizen observatories (COs) and Do it Yourself (DIY) initiatives. This includes four focused on biodiversity: Artportalen, iSpotnature, Natusfera, Pl@ntNet; and five focused on the environment: CanAirIO, FreshWater Watch, iSPEX , Kduino, and OdourCollect.

As part of Cos4Cloud these COs play key overlapping roles as they provide a wide range of expertise contributing to the delivery of the project. This includes the development of technological services; as users and contributors integrating, testing and providing feedback; as well as demonstrators and core stakeholders sharing the services with their user communities exemplifying the outputs of Cos4Cloud i.e. citizen science technologies, supported by their own outreach and engagement with audiences targeted by Cos4Cloud. This report, **D6.2 Guidelines on best practice for COs as part of the outreach methodology** seeks to highlight some of these contributions.

The focus of this report is to demonstrate best practice in citizen observatories through the experiences of COs directly involved in the project. This is supported through delivery of ***Task 6.2 Sharing best practice***. It brings together insight from a number of sources: networking and engagement with projects of interest; sharing between the COs in Cos4Cloud (i.e. discussions, workshops internal and external reports etc); from the COs contributions / involvement in the co-design of the technological services; and from two questionnaire surveys facilitated with the CO leads gathering feedback to directly capture information, best practice and lessons learned. This has been collated contributing to knowledge transfer and consolidated into the development of guidelines of best practice which are being shared through the Cos4Cloud Toolbox and Evidence Hub.

This report is part of Work Package 6 **(WP6)** ***Networking, Training [Education] and Capacity Building***. It is part of the project's efforts facilitating networking and citizen science knowledge management processes across organisations, people and initiatives, one of the key objectives of the Cos4Cloud project. It also includes collating, documenting and sharing of these as outputs and deliverables in the following ways:

- Cos4Cloud best practice for COs report i.e. as **T6.2 Sharing best practice** and **D6.2, Guidelines on best practice for COs as part of the outreach methodology (this report)**

- Collated Cos4Cloud CO best practice i.e. as **MS28 Best practice guidelines and resources**, and
- Documented demonstration examples of Cos4Cloud CO activities i.e. as **T6.3.3 Implementation of case studies**

This report explores Cos4Cloud's delivery in the context of the experiences of the COS involved in the project. This helps to present these as summary results and guidelines on Cos4Cloud's approach as an outreach methodology as well as best practice of relevance to other CO's and projects of interest. An important part of this is fostering sustainability, with the help of these services, and this includes providing guidelines, best practice and building capacity, including these citizen science communities, in the continued use of these services. Results are also documented as best practice guidelines and resources shared as outputs supporting other citizen observatories and other stakeholders, collectively accessible via the Cos4Cloud Toolbox and Evidence Hub i.e. **D6.3 Citizen-science toolbox and evidence hub (i.e. The Cos4Cloud Toolbox and Evidence Hub).**

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Figures and Tables

1. Introduction

Co-designed Citizen Observatories Services for the European Open Science Cloud (Cos4Cloud, https://cos4cloud-eosc.eu/) is developing thirteen technological services focused on boosting citizen science observatories to help increase and improve the quantity and quality of observations.

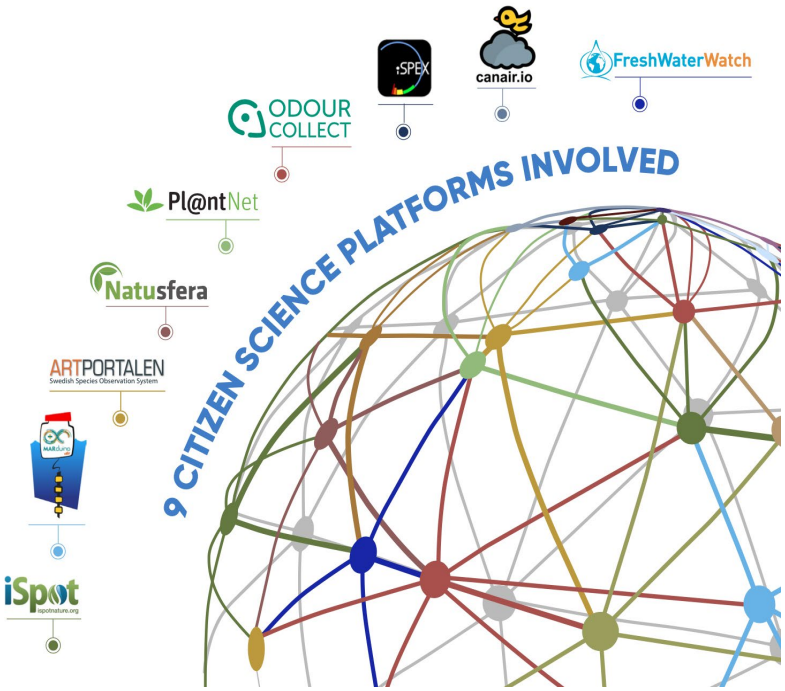
Cos4Cloud includes the participation of nine established citizen observatories (COs) and Do it Yourself (DIY) initiatives. This includes:
Four focused on the biodiversity:

- Artportalen (https://www.artportalen.se/)
- iSpotnature (https://www.ispotnature.org/)
- Natusfera (https://natusfera.gbif.es)
- Pl@ntNet (https://plantnet.org/en/)

And five focused on the environment:

- CanAirIO (https://canair.io/)
- FreshWater Watch (https://www.freshwaterwatch.org/)
- iSPEX (https://ispex.org/)
- Kduino (http://www.citclops.eu/transparency/measuring-water-transparency)
- OdourCollect (https://odourcollect.eu/)

Figure 1 Citizen observatories in Cos4Cloud



These citizen observatories are led by members of the Cos4Cloud Consortium and, as part of the project, play key overlapping roles providing a wide range of expertise contributing to delivery. This includes the development of technological services; as users and contributors integrating, testing and providing feedback; as well as demonstrators and core stakeholders sharing the services with their user communities exemplifying the outputs of Cos4Cloud i.e. citizen science technologies, supported by their own outreach and engagement with audiences targeted by Cos4Cloud.

This report, **D6.2 Guidelines on best practice for COs as part of the Cos4Cloud outreach methodology,** seeks to highlight some of these contributions from the experiences of the COs involved in the project. It is part of the project's efforts supporting citizen science knowledge management processes across organisations, people and initiatives which is one of the key objectives of the Cos4Cloud project.

D6.2 is part of Work Package 6 **(WP6)** ***Networking, Training [Education] and Capacity Building.*** The main goal of WP6 is to demonstrate new conceptual models for evidence-based knowledge exchange, capacity-building, best practice, learning and engagement with and for citizen science, focusing on citizen observatories and integration in the European Open Science Cloud. At the same time collating, documenting and sharing these as outputs and deliverables. It also directly contributes to:

- Cos4Cloud best practice for COs as part of **T6.2 Sharing best practice**
- Collated Cos4Cloud CO best practice as **MS28 Best practice guidelines and resources**, and
- Documented demonstration examples of Cos4Cloud CO activities i.e. as **T6.3.3 Implementation of case studies**
- Knowledge transfer consolidated and collated in the development of resources, based on the experiences of these COs, i.e. project outputs, which are being shared through **the Cos4Cloud Toolbox and Evidence Hub (D6.3).**

This D6.2 report demonstrates best practice, lessons learned, information etc. from citizen observatories (COs) through the experiences of the nine COs directly involved in the project. This was collected mainly from two survey questionnaires facilitated with the CO leads to directly gather their feedback. It also brings together insight from other sources:

- Networking and engagement with projects of interest; sharing between and amongst the Cos4Cloud COs and others (i.e. discussions, workshops internal and external, reports etc);
- From CO contributions / involvement in the co-design of the technological services.

This deliverable:

- Summarises the research conducted around citizen observatories and best practice, in the context of Cos4Cloud.
- Summarises the research conducted around outreach, in the context of citizen observatories, and outreach as part of Cos4Cloud communication strategy.
- Shares collated results from two Cos4Cloud Citizen Observatory (CO) surveys conducted with the COs in the project:
    - **CO Survey 1**[1] collected information including: attributes and characteristics i.e. Introductory / general information, data collection, geographical focus, technical information, outreach & engagement, training and educational tools and resources, use, impact and lessons learned.
    - **CO Survey 2**[2]: collected information including perspectives, suggestions and comments from the CO leaders about experiences being a CO associated with Cos4Cloud.
- Highlights CO best practice from experiences associated with Cos4Cloud project activity that may be of direct relevance to other citizen observatories to help them make the best use of the project's outputs.
- Highlights examples of outreach and engagement (i.e. activities, approaches, etc.) implemented by the COs with their communities and stakeholders, as examples of best practice of relevance to other citizen observatories and projects of interest.
    - Introduces ***Guidelines on best practice for building citizen observatories*** resources which will be available in the **Cos4Cloud Toolbox and Evidence Hub** as part of this collection of outputs from the project. This includes: how a CO can apply best practices modelled within a framework similar to Cos4Cloud and how examples of best practice from the nine COs involved in Cos4Cloud can be applied or adapted in similar contexts.
    - Concludes with a summary of strategies contributing to: meeting the challenges facing COs, building a legacy for Cos4Cloud with the COs involved in the project, other COs, stakeholders and projects of interest; as well as in enhancing the tole of citizen science in the European Open Science Cloud (EOSC)beyond the lifetime of the project.

Work summarised in this D6.2 report supports and or contributes to the following tasks, and subtasks across ***WP5: Cos4Cloud Services in Practice; WP6: Networking, Training [Education] and Capacity Building*** and ***WP8 Communication, outreach and stakeholder engagement:***

[1] CO Survey 1, June, 2020 Appendix 1
[2] CO Survey 2, December 2022, Appendix 2

T5.1: Co-design services
T5.3.1: Bioblitzes
T6.2: Sharing best practice
T6.3: Production of a citizen-science toolbox and Evidence Hub
T6.3.1: Design, infrastructure planning and development within a co-designed / co-created process
T6.3.2: Addition and creation of training resources, case studies etc.
T6.3.3: Implementation of case studies
T6.3.4: Integration of an Evidence Hub
T6.4: Evaluation of citizen engagement, educational learning methodologies and citizen science impact
T6.5: Training and capacity building services
T8.2.6 Promote, design and layout the key project's outputs

This **D6.2 Guidelines on best practice for COs as part of the outreach methodology** report, also supports and or contributes to the following additional ***deliverables:***
D6.3: Citizen-science toolbox and evidence hub (i.e. the Cos4Cloud Toolbox and Evidence Hub). Demonstrator: An on-line 'one-stop-shop' of guidelines and materials for existing and future citizen-observatory leaders.
D6.4: Report to demonstrate the Cos4Cloud engagement model. Report: Demonstrate how the model for long-term, large-scale engagement in citizen science using the EOSC hub has been implemented, monitored and evaluated in the project.
D6.5: Design and evaluation of school-based CS activities.
Report: present the general design model and the implementation approach of the school-based CS activities.

2. Citizen observatory best practice: contributing to the outreach methodology for Cos4Cloud

The development of COs and the synergy with citizen science has been well documented in current practice. This includes the role these initiatives play advancing scientific knowledge and promoting public participation in science (PPSR) and the role as a. a bridge between scientists, researchers and the public. Citizen science includes collecting observations in a range of disciplines contributing data from different settings and timescales and citizen observatories are described as providing the technological platforms, tools and features (i.e. websites, applications and devices) as the "research infrastructures" that support this.[3]

COs help to facilitate larger scale participation in in citizen science activities through the integration of information and communications technologies. These provide digital connections which enhance the capacity of citizens to contribute observations and the sharing of information[4]. Based on the results of an extensive research, categorising and mapping COs are also described as "a particular form of citizen science and collective action with the aim to create evidence and knowledge and to apply the evidence for advocacy and place-based decision making to reach environmental and societal impact."[5.] COs support citizens and an array of stakeholders (i.e. scientists, policymakers etc.), through the use of supportive information computer technology (ICT) within a dedicated platform and or application structure facilitating mechanisms for data collection as well as the possibility for data interpretation and information sharing. [6]

The breadth, scope and potential for COs, as well as the role they play, particularly in Europe, has been supported through a number of initiatives funded with European funding[7]. Examples include: FP7 (ENV.2012.6.5-1: Developing community-based environmental monitoring and information systems) and H2020 (SC5-17-2015: Demonstrating the concept of 'Citizen Observatories', H2020-EU.3.5.5.: Developing comprehensive and sustained global environmental observation and information

[3] Mominó, J. M., Piera, J., & Jurado, E. (2017). Citizen observatories as advanced learning Environments. *Analyzing the Role of Citizen Science in Modern Research*, 192-212.
[4] Momino, 2017 et al.
[5] WeObserve consortium (2021). Roadmap for the uptake of the Citizen Observatories' knowledge base. Report submitted to the European Commission. DOI: 10.5281/zenodo.4646774
[6] Liu, H-Y, Grossberndt, S and Kobernus, M. 2017. Citizen Science and Citizens' Observatories: Trends, Roles, Challenges and Development Needs for Science and Environmental Governance. In: Foody, G, See, L, Fritz, S, Mooney, P, Olteanu-Raimond, A-M, Fonte, C C., Antoniou, V. (eds.) *Mapping and the Citizen Sensor.* Pp. 351–376. London: Ubiquity Press. DOI: https://doi.org/10.5334/bbf.o. License: CC-BY 4.0
[7] Gold, M. (2018). D2. 1 EU citizen observatories landscape report—frameworks for mapping existing CO initiatives and their relevant communities and interactions. *Zenodo. DOI*, *10*.

systems, as well as SC5-19-2017: Coordination of citizens' observatories initiatives. Common themes have emerged from these initiatives which have helped to further define them i.e. utilising the "capabilities" of their own smartphones, laptops, social media etc., which enhances the possibilities for environmental monitoring and citizens involvement and action.

For example, WeObserve, was developed to, amongst other things, improve coordination between COs by supporting "the growing number of citizen science observatories in Europe" [8]; bringing them together to share and consolidate knowledge and identify best practices[9] towards a "sustainable ecosystem of COs"[10]. The project's concluding roadmap for the future of COs further identifies disseminating and supporting best practices and its role as important.

Cos4Cloud focuses on boosting citizen science technologies and integrating this within the European Open Science Cloud (EOSC) contributing to the viability and sustainability of COs. Delivery through the co-design of innovative services that solve challenges faced by citizen observatories (COs), is an overarching ambition of Cos4Cloud. In doing so, Cos4Cloud has developed 13 technological services to help boost observations, involving 9 established COs as part of the process. Supporting this as part of this process WP6 focuses on the collation and sharing of best practice from the perspectives and experiences of the COs involved. Best practice developed can support other COs and collating and sharing this is part of the outreach methodology for codesigning citizen observatories services for the EOSC-Cloud: Cos4Cloud.

2.1 CO common features

Alongside the growth of citizen science there has been a wide range of shared guidance documents, principles, reports, toolkits etc targeting new and existing citizen science projects and COs. This has emerged in response to an identified need for more integration of approaches and collaboration focused on sharing knowledge. Emerging with this is an emphasis on the role of guidelines and best practice and this has been noted particularly in the context of supporting the design and management of COs.

[8] Bio Innovation Service (2018) Citizen science for environmental policy: development of an EU-wide inventory and analysis of selected practices. Final report for the European Commission, DG Environment under the contract 070203/2017/768879/ETU/ENV.A.3, in collaboration with Fundacion Ibercivis and The Natural History Museum, November 2018.

[9] WeObserve consortium, 2021.

[10] Gold, M., Wehn, U., Bilbao, A., Hager, G. (2020). EU Citizen Observatories Landscape Report II: Addressing the Challenges of Awareness, Acceptability, and Sustainability. WeObserve Deliverable 2.4 Update: EU landscape of existing citizen observatory initiatives/projects, associations and networks. Submitted to the European Commission.

"Learning from practice" is a core part of this: COs have their own unique characteristics therefore the process of sharing and gathering experiences allows for better understanding of the "enabling environment needed for citizen observatories to achieve their full potential." [11]

Through a comprehensive review, Liu et al[12] propose that in practice, COs share a common model, demonstrating the core criteria required for a CO. This includes:

i. engaging the participation of citizens in data collection,
ii. data interpretation and information delivery,
iii. a structured system based on:
    a. identifying what citizens want and what they can offer
    b. exploring what products and services a CO can provide
    c. recruiting and retaining participants
    d. supporting participants to report or upload observations
    e. supporting participants to access/receive information
iv. interaction with citizens and other stakeholders,
v. data collection tools, and
vi. an ICT infrastructure.

With the concept of COs still evolving, other contributions are required to further explore their full potential for the future. The landscape is open to more discussions and through the involvement of COs, Cos4Cloud seeks to play a role contributing to this growing body of knowledge through the direct involvement of experienced COs.

2.2 Defining CO best practice: the ECSA Ten Principles of Citizen Science

Best practices can be described as "solutions, policies, interventions, actions, or procedures that are deemed successful and may assist other entities grappling with similar challenges." [13] In the context of this report we can view best practice as guidelines

[11] Gold, M., Wehn, U. ,(2020). Mission Sustainable: Fostering an enabling environment for sustainable Citizen Observatories. WeObserve policy brief 2. Zenodo. https://doi.org/10.5281/zenodo.4001672

[12] Liu, H-Y, Grossberndt, S and Kobernus, M. 2017. Citizen Science and Citizens' Observatories: Trends, Roles, Challenges and Development Needs for Science and Environmental Governance. In: Foody, G, See, L, Fritz, S, Mooney, P, Olteanu-Raimond, A-M, Fonte, C C., Antoniou, V. (eds.) *Mapping and the Citizen Sensor.* Pp. 351–376. London: Ubiquity Press. DOI: https://doi.org/10.5334/bbf.o. License: CC-BY 4.0

[13] Adapted by Oliver Blake, Meredith Glaser, Luca Bertolini & Marco te Brömmelstroet (2021) How policies become best practices: a case study of best practice making in an EU knowledge sharing project, European Planning Studies, 29:7, 1251-1271, DOI: 10.1080/09654313.2020.1840523

which are developed after years of trial and error or established as well as through research setting guidelines for others that can produce good outcomes if followed. [14]

The European Citizen Science Association's (ECSA) Ten Principles of Citizen Science[15] , the main guiding best practice framework for citizen science, can be used to help define this further. Developed by ECSA's Sharing best practice and building capacity working group, members collaborated and shared knowledge leading to the development of the ECSA Ten Principles of Citizen Science (also referred to as "ECSA Ten Principles"). Since it was first launched, this has grown to become one of the most utilised guides, applied to a wide range of settings (translated into over 30 languages), influencing the development of other best practice for citizen science in a variety of settings.[16]

ECSA's Ten Principles of Citizen Science covers relevant themes, "serving as a principled guide for all citizen science project developers and practitioners"[17], which are applicable to COs. Efforts focused on defining principles for mobile apps and platforms for citizen science (i.e. COs) recommended that close connections should be made to the ECSA Ten Principles as this supports planning, design, management and the implementation of best practice. There is also evidence of efforts by CO platforms and citizen science initiatives to review their operations in the context of the Ten Principles. For example, a review conducted by CO MammalWeb referencing the Ten Principles, described using it as a reference point as it "underlies good practice in citizen science". Mammalweb[18] reviews and considers each principle, in turn, in relation to that platform.

2.3 Best practice for COs: Aligning outreach with other Cos4Cloud participatory methodologies and approaches

COs are regarded as a significant development in the growth of citizen science playing an important role as a means to engage the public in the development of scientific knowledge, using a range of citizen science methods, digital tools, sensors for data gathering, and sharing information while motivating change[19]. Communities can monitor,

[14] Wright, G., Best practice, https://www.techtarget.com/searchsoftwarequality/definition/best-practice#:~:text=A
[15] ECSA (European Citizen Science Association). (2015). Ten Principles of Citizen Science. https://doi.org/10.17605/OSF.IO/XPR2N. https://zenodo.org/record/5127534#.Y_eAYa2ZNPZ
[16] Robinson, L.D., Cawthray, J.L., West, S.E., Bonn, A. and Ansine, J., 2018. Ten principles of citizen science. In *Citizen science: Innovation in open science, society and policy* (pp. 27-40). UCL Press
[17] Sturm U, Schade S, Ceccaroni L, Gold M, Kyba C, Claramunt B, Haklay M, Kasperowski D, Albert A, Piera J, Brier J, Kullenberg C, Luna S (2017) Defining principles for mobile apps and platforms development in citizen science. Research Ideas and Outcomes 3: e21283. https://doi.org/10.3897/rio.3.e21283
[18] Mammal Web and the 10 Principles of Citizen Science: https://www.mammalweb.org/en/about/mammalweb-and-the-10-principles-of-citizen-science
[19] WeObserve consortium, 2021.

observe and report on biodiversity and their environment, on a local scale over a period of time, (typically long term)[20].

Citizen science and COs practice involves a wide range of activities involving outreach, public participation in scientific research (PPSR), public engagement with science (PES), informal science education / learning, community science, crowd-based / crowd-sourced science and volunteer monitoring. Importantly too, the use of technology, and the impact this has had on citizen science projects has also contributed to the growth of COs. In addition to the identification of guidelines of best practice, framed by themes from the ECSA Ten Principles, above; this report focuses on identifying best practice from the COs linked to Cos4Cloud as part of the outreach methodology for Cos4Cloud.

Outreach

As a communications method, outreach involves making contact or explaining information about a project or initiative, to a particular group. Associated with the public understanding of science, it is viewed as a one-way process of experts communicating to the public. With the growth of public engagement, a two-way process involving "mutual learning" between those transmitting information / knowledge and the audience[21] outreach is used as part of a collection of approaches to involve participants. Implemented in combination with communication and engagement, other methods and approaches; outreach supports mechanisms that facilitate public participation in scientific research (PPSR) i.e. citizen science through the dissemination of materials, resources, educational content etc.

In citizen science, outreach can also be linked to research and or education. For example, as part of the delivery of Open Air Laboratories (OPAL), a major UK-wide citizen science initiative, outreach provided information, learning and training possibilities for potential participants, building awareness as well as impacting on behaviour. While at the same time promoting understanding and engagement with science (i.e. biodiversity or the environment) towards achieving societal impact. [22]

In Cos4Cloud, COs are defined as research infrastructures and outreach is delivered as part of engagement, one of the central elements of the communication strategy which focuses on the identification and description of the target groups; selecting the most

[20]Gold, 2018.

[21] McCallie, E., Bell, L., Lohwater, T., Falk, J. H., Lehr, J. L., Lewenstein, B. V., Needham, C., and Wiehe, B. 2009. Many Experts, Many Audiences: Public Engagement with Science and Informal Science Education. A CAISE Inquiry Group Report. Washington, D.C.: Center for Advancement of Informal Science Education (CAISE)

[22] Lakeman-Fraser, P., Gosling, L., Moffat, A.J., West, S.E., Fradera, R., Davies, L., Ayamba, M.A. and van der Wal, R., 2016. To have your citizen science cake and eat it? Delivering research and outreach through Open Air Laboratories (OPAL). BMC ecology, 16(1), pp.57-70.

appropriate communication channels; and devising key messages to raise awareness of the initiatives and results of Cos4Cloud among the project's target audiences. This includes outreach materials and tools to make the project understandable and attractive to different stakeholders.[23]

The Cos4Cloud COs use outreach as part of their engagement and participation and have been involved in communication actions such as engaging users to participate in testing the Cos4Cloud services as well as a range of other activities contributing to project delivery. This D6.2 report focuses on best practice from COs, as part of the process of documenting Cos4Cloud's approach as an outreach methodology. In doing so outreach is viewed as a complementary method contributing to project communications and supports the Cos4Cloud engagement model[24]. Important too are links to dissemination and exploitation (D7.3) and D6.6 which focuses on the capacity building approaches and training resources supporting Cos4Cloud's technological services.

As part of this, Cos4Cloud's outreach as a methodology, is aligned with multi-dimensional approaches, which together support and facilitate engagement and participation to reach key publics and stakeholders. These include:

Agile methodology: An agile methodology guides the phases of development, testing and validation of the services integrating understanding of user journeys, motivations, as well as the roles and purposes of COs and their communities, and associated stakeholders.

Co-design: Cos4Cloud's codesign process has involved organising several co-design activities with end-users and other stakeholders collecting ideas, needs and expectations towards the Cos4Cloud technological services in the development and testing of the services.

Communications, outreach & stakeholder engagement: This includes aligning communications, stakeholder engagement and outreach with different approaches, tools and techniques (i.e. engagement and outreach) as part of the Communication Plan[25] (WP8) to reach different target groups, maximising the project's effort to create interest and understanding of the Cos4Cloud project. Also key is ensuring best practice resources align with this and the design meets Cos4Cloud brand requirements.

[23] Cos4Cloud Consortium (2020). Ansine, J., Daskolia M., Grillia N., Gkotzos D., Justamante A., Liñán S., Nolland K., Piera J., Ramón, A., Rodríguez-Arias M.A., Soacha K., Woods S., Woods T., Kakaroucha E. Communications plan- Report (D8.2). Co-designed Citizen Observatories Services for the EOS-Cloud (Cos4Cloud).
[24] D6.4 Report to demonstrate the Cos4Cloud engagement model.
[25] D8.2 Cos4Cloud Communication Plan, 2020.

Dissemination and exploitation: The exploitation roadmap, dissemination plan and marketing strategy (WP7) are key considerations in the development and implementation of resources and activities that demonstrate Cos4Cloud outputs. This process involves creating dissemination approaches to engage with stakeholders from projects of interest, etc.

Engagement: Cos4Cloud's approach to engagement, combines the conceptual 'hook' model proposed by Eyal (2014)[26]. With a focus on converting external triggers into internal triggers, utilising the hook i.e. action as well as rewards creating habit-forming engagement with (b) the layered model of social experience proposed by Yamakami (2014)[27] based on citizen relationships with internet services and games i.e. for the habit to really form, the user has to invest in it.

Interoperability: One of the core objectives of Cos4Cloud is contributing to solving current CO challenges, focused on interoperability and innovative models of collaboration, by developing services that improve networking, data quality and security within the citizen observatories.

Networking, Training, [Education] & Capacity Building: Activities supporting capacity building and generating best practices are key outputs of Cos4Cloud to reach, involve and engage with stakeholders. This is particularly focused on demonstrating how Cos4Cloud can sustain long-term participation by integrating: strategies designed for citizen engagement, knowledge transfer and capacity building (i.e. of the services) supporting key stakeholder groups to strengthen networks etc. and fostering citizen science learning and education particularly in school populations.

3. Cos4Cloud and citizen observatories

COs can be defined as "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."[28]

COs engage citizens and other stakeholders in community-based environmental monitoring providing data to help address issues such as global warming, biodiversity

[26] Eyal, N. (2014). Hooked: How to build habit-forming products. Penguin.
[27] Yamakami, T. (2014). A layered view model of social experience design: Beyond single-user user experience. In Advances in Computer Science and its Applications (pp. 35-41). Springer, Berlin, Heidelberg.
[28] Momino, 2017

decline and natural disasters.[29] They build on innovative and novel observation applications and web-based technology which can also be embedded in portable or mobile personal devices.[30] They are recognised as an important part of the growth of citizen science particularly in the roles they play. COs help communities monitor and report on environmental matters that interest them, access information, develop skills, as well as contribute to policy and wider decision-making[31]. CO participants not only provide data but play key roles i.e. crowdsourcing data co-creation (collating observations), data validation (confirming IDs) and data analysis.

By focusing on co-designing innovative services, Cos4Cloud's outreach approach includes supporting stakeholders, CO managers, user communities, etc. in the use of these services and other outputs. This outreach methodology seeks to respond to the needs of COs, in their organisational role, but also includes engaging the participants / individuals who are part of the CO user communities. The landscape of COs and other projects and initiatives of interests is vast: with lists and inventories of CS activity and initiatives in the hundreds[32] and thousands[33] with different strategies and techniques adopted to reach stakeholders.

An earlier Cos4Cloud report (D6.1) identified a range of these COs as stakeholders laying the groundwork for outreach, engagement and communication etc, researching and identifying possible projects of interest to Cos4Cloud and 78 citizen observatories and other initiatives of interest were identified. This background has been key to considering the role of COs in Cos4Cloud and gathering best practice from project experiences. This aligns with other Cos4Cloud methodologies which have also influenced the design, development and implementation of resources as part of the **Cos4Cloud Toolbox and Evidence Hub (D6.3)**.

3.1 Attributes and characteristics of COs

[29] Gold, M., Wehn, U. ,2020.

[30] SC5-19-2017: Coordination of citizens' observatories initiatives call (https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/sc5-19-2017)

[31] Rubio-Iglesias, J.M. (2013) Citizens' observatories for monitoring the environment: A commission perspective. In Proceedings of the Workshop on Citizen's Involvement in Environmental Governance, Arlon, Belgium, 7 October 2013; Directorate General Research and Innovation, European Commission: Brussels Belgium

[32] An inventory of Citizen Science activities' in 2018 collated over 500 initiatives across and beyond Europe. European Commission, Directorate-General for Environment; European Commission, Joint Research Centre; Bio Innovation Service(2018): An inventory of citizen science activities for environmental policies. European Commission, Joint Research Centre (JRC) [Dataset] PID: http://data.europa.eu/89h/jrc-citsci-10004. https://www.eea.europa.eu/about-us/who/epa-network

[33] SciStarter (www.scistarter.org), an online community aimed at improving CS experiences lists over 3,000 projects and events.

Cos4Cloud's review of projects of interest included a range of attributes and characteristics adapted from different reviews and inventories of citizen science activities[34]. For example, the aim, geographic scope, project duration, target groups, what they monitor, and type of data collected as well as how data is collected, interpreted, visualised disseminated and the technologies used to do so are important properties to identifying the scope and reviewing common concepts and practices of COs.[35] A combination of these were particularly useful in the identification of core criteria used to gather information about the COs involved in Cos4Cloud. Key attributes informing this include:

Project Information:	
Name	Name of the project / portal / initiative
Description	Description of the project / portal / initiative
Website URL	Link to the website of the project / portal / initiative
Environmental Topic / Theme / area	Environmental topic / theme / area / data collection focus[36]: Air quality Biodiversity, nature and landscapes Climate Land Noise Sustainable consumption and production Waste Water Efficient use of resources Transport and energy use Animal welfare Environmental risks Environmental health Other (specify)
Timeline	Timeline including: start year, end year or ongoing
State	Active, Finished, Future
Geographic coverage	Specify country / region; whether national, international or regional etc

3.2 Introducing the COs involved in Cos4Cloud

[34] Gold, 2018
[35] Liu, H. Y., Kobernus, M., Broday, D., & Bartonova, A. (2014). A conceptual approach to a citizens' observatory–supporting community-based environmental governance. *Environmental Health*, *13*, 1-13.
[36] Theme / Topic/ Area attributes adapted from: An inventory of citizen science activities for environmental policies. European Commission, Joint Research Centre (JRC), (cited earlier).

Generally characterised by their focus on the environment, the scale of the activities involved and a timeline which is typically long term, findings from research and analysis of citizen science and COs also note typologies, key attributes / properties, and characteristics as important (i.e. the length of time required to engage and build a community of participants and the use of innovative data collection tools and technologies). Citizen observatories have also been characterised by the following commonalities[37]:

- Participation of citizens in environmental monitoring (and governance)
- Facilitating the (bi-directional) flow of data / information
- Host citizen-generated observations
- Use mobile and web technologies

These defining characteristics, commonalities and attributes also present challenges to their sustainability.[38] Cos4Cloud's approach, focuses on providing support by co-designing innovative services, developed with the input of nine associated COs, to help meet what the project identifies as core challenges[39] facing COs, in particular:

- Capturing, identification and validation of data
- Interoperability at local, regional and global scale
- Long term sustainability challenges

This report explores Cos4Cloud's approach in the context of the experiences of the COS involved in the project. This helps to present these as summary results and guidelines on Cos4Cloud's approach as an outreach methodology as well as best practice of relevance to other CO's and projects of interest. An important part of this is fostering sustainability, with the help of these services, and this includes providing guidelines, best practice and building capacity, including these citizen science communities, in the continued use of these services.

Cos4Cloud includes the participation of nine citizen observatories and Do it Yourself (DIY) initiatives, collectively referred to as COs, focused on biodiversity and the environment introduced below. The summaries of each CO, below, are collated from the following sources: information provided by the CO leads (from survey information[40]), the platform websites as well as details summarised on the Cos4Cloud website available here: https://cos4cloud-eosc.eu/citizen-science-innovation/cos4cloud-citizen-observatories/.

[37] Gold, M., et al, 2020

[38] Gold, M., et al, ibid.

[39] Piera, J., & Cos4Cloud Consortium. (2020). Integrating Citizen Science in the European Open Science Cloud 'Cos4Cloud': a minimum viable ecosystem (MVE) for tackling common challenges of citizen observatories. (accessced at: https://digital.csic.es/handle/10261/240848).

[40] CO Surveys, Appendices 1 and 2.

3.2.1 Cos4Cloud COs focused on Biodiversity

Artportalen is the Swedish Species Observations System, a citizen observatory that reports biodiversity observations in Sweden (i.e. plants, animals and fungi). Observations are recorded in four obligatory fields: taxa, location, date and reporter. Additional information can be uploaded, for example activity (breeding, migrating etc), observation method, determination method or habitat.

The platform also offers the ability to create projects, define own parameters, field diaries, mapping and presentation, communication among users, as well as specific functions for particular users. Observations can be reported from desktop PCs or via mobile devices. A checklist feature enables the user to generate a list of species likely to occur at a particular location on a particular date. By confirming that all species that were seen and identified are reported, the observer submits a complete list and the species not observed become important zero-observations.

Reporting modules, such as the Invasive and Alien Species (IAS) checklist feature, have been built using Artportalen's API. This API has also enabled third-party developers to build apps to read information, report observations or both. An alarm service is under development enabling users to receive a notification when relevant observations are reported.

Artportalen has received more than 78,000,000 observations of birds, plants, insects, fungi and many other taxa along with the 1,300,000 associated media files. Nearly 4,000,000 of the observations that Artportalen has received have been validated by expert validators or committees.[41]

One feature of Artportalen is the way data has become fundamental to environmental management in Sweden. Authorities and governmental agencies use data from the platform, via their own web interfaces, as a primary source of information on biodiversity. As such, the platform plays a pivotal role in governance and decision-making and leads to more transparency in the decision-making process since the data used is open to everyone.

[41] Source: Cos4Cloud's Artportalen description: https://cos4cloud-eosc.eu/citizen-science-innovation/cos4cloud-citizen-observatories/artportalen/

Arportalen was launched in 2000, is funded by the Swedish Environmental Protection Agency and operated by Cos4Cloud partner the Swedish University of Agricultural Sciences (SLU) Swedish Data Bank.[42]

iSpot - your place to share nature is a citizen observatory on biodiversity that encompasses a network of over 80,000 global nature observers who have crowdsourced the identification of 30,000 taxa, through over 1,500,000 images of more than 750,000 observations of different species.[43]

iSpot, focuses on species identification and building identification (ID) skills. Users are encouraged to share their interest with a friendly, online community, explore the latest spots, join discussions, post observations, get help with IDs while building their user profile reputation. Users can participate in iSpot by submitting observations including photos of any of the following groups:

- Amphibians and Reptiles
- Birds
- Fish
- Fungi and Lichens
- Invertebrates
- Mammals
- Other organisms
- Plants

Developed and managed by Cos4Cloud partner The Open University (OU), iSpot was launched to the public in 2009. iSpot is in English and has a geographical coverage across the British Isles, as well as Europe and internationally. iSpot's citizen science activities have been integrated into and contribute to OU teaching, including modules and courses; iSpot also facilitates informal and non-formal science learning through OU-BBC co-productions and free learning resources.

iSpot data is also a research-grade tool for investigations on biodiversity, making an important contribution to national strategy and policy in associated areas. For example, iSpot was part of a partnership initiative, funded by Defra, to define a National Pollinators Monitoring Scheme. Additionally, the value of citizen science through tools like iSpot is explicitly mentioned in policy supporting reports and documents. For example, the 2011

[42] Source: Artportalen website: https://www.artportalen.se/Home/About
[43] Source: CO survey 2, December 2022

UK Government Natural Environment White Paper[44] notes iSpot as a means to 'Reconnecting people and nature'. iSpot is also a partner of the State of Nature Partnership, a collaboration between a number of conservation and research organisations in the UK contributing to the 2016, 2019 and upcoming State of Nature Reports.

Natusfera is one of the largest citizen observatory platforms in the biodiversity domain[45]. The main objective is to share biodiversity learning with the whole community by reporting observations on all sorts of living beings through its app.

Natusfera is a space to register, organise and share different types of biodiversity observations, including photo sharing and location. It is described as 'virtual field notebook that allows users to add their observations to a cloud-based system, connecting and talking with other naturalists who can help identify what is seen[46].

The platform allows for the creation of dedicated projects with all sorts of geographical scope (invasive species, lichens, marine biodiversity, etc.). Users can participate in the several projects available or create their own.

Users participate in Natusfera by posting observations including photos of any of the following groups:

- Birds
- Amphibians and Reptiles
- Fish
- Fungi and Lichens
- Invertebrates
- Mammals
- Other organisms
- Plants

[44] Department for Environment, Food & Rural Affairs (DEFRA) (2011) The Natural choice: securing the value of nature, Ref: ISBN 9780101808224, Cm. 8082, UK. https://www.gov.uk/government/publications/the-natural-choice-securing-the-value-of-nature
[45] Source: https://cos4cloud-eosc.eu/citizen-science-innovation/cos4cloud-citizen-observatories/natusfera/
[46] Source: https://cos4cloud-eosc.eu/citizen-science-innovation/cos4cloud-citizen-observatories/natusfera/

Natusfera was launched in June 2016 and is managed by a consortium of organisations, among them three Cos4Cloud partners: Bineo Consulting[47], CSIC and CREAF. Based in Spain, Natusfera is available in English, Spanish, Catalan, Galician, Basque, Italian and geographical coverage includes local, national, European as well as some international observations. More than 21,000 citizen scientists have participated and it has received more than 270,000 observations of over 12,600 species[48]. Natusfera has been adopted as the citizen science platform for the Spanish node of the Global Biodiversity Information Facilities (GBIF), which covers the basic infrastructure costs.

Pl@ntNet is a participatory citizen science platform for collecting, sharing and reviewing plant observations based on automated identification. Its objective is to monitor plant biodiversity and facilitate access to plant knowledge by the general public.

Available as both a website and an app, both frontends of the platform are used by a large community of several million users who produce hundreds of thousands of plant observations daily posting a total of over 14 million images of more than 37,000 species[49]. This data stream is of high interest for many research domains, including ecology, agronomy and energy. This free app helps identify plant species from photographs using visual recognition software which means users can submit a photo of any plant through the app and it will help to identify the species using artificial intelligence (AI).

The Pl@ntNet app also improves its performance with each observation (new species, new training data, revised quality, etc.). The validated observations are integrated into the world's largest repository of biodiversity occurrences (GBIF). Pl@ntNet's workflow and dataflow is of great interest to researchers and citizen science stakeholders in various domains (data sciences, ecology, biodiversity, phenology, plant health, agrifood, etc.).

Pl@ntnet is managed by an open consortium currently including four French research organisations (Cos4Cloud partner INRIA, as well as CIRAD, INRAE and IRD) and the Agropolis Foundation[50]. Based in France, its geographical coverage includes local, national, European and international observations and is available in 23 languages. Launched in 2011, over the years, it has become a worldwide ecosystem with millions of

[47] The mobile version of Natusfera is based on Naturapp developed, managed and licensed by Bineo Consulting.
[48] Source: Natursfera website: https://natusfera.gbif.es/
[49] Source: Pl@ntNet website: https://plantnet.org/en/ and Cos4Cloud website: https://cos4cloud-eosc.eu/citizen-science-innovation/cos4cloud-citizen-observatories/plntnet/
[50] Source: CO Surveys and Plantnet website.

end-users and tens of active partners all around the world (museums, national parks, gardens, herbaria, territorial authorities, schools, associations, etc.).

3.2.2 Cos4Cloud COs focused on the Environment

CanAir.io is a Colombian citizen observatory that uses mobile and fixed sensors to monitor air quality. Mobile phones (mobile measurement) or Wi-Fi (fixed measurements) are used with low-cost technology (i.e. Do-It-Yourself devices) and open-source code. Concerned about the pollution in the city generated by old technologies, it was started to gather data from Bogotá, Colombia[51].

CanAirIO measures air quality Particle Material (PM) 2.5 and aims to build a citizen network, as an air-quality map that will "allow us to know what we are breathing and how we can improve quality of life"[52]. The data collected, can contribute to independently validating official air-quality numbers noting the possibility that what can be measured can be improved. This knowledge can empower citizens to demand better air quality policies Up to December 2022 there were 400 mobile users and 25 fixed stations[53].

This citizen observatory uses the CanAirIO device to track air quality in any world region. CanAirIO is a Do It Yourself (DIY) device, which helps users build their own version, in a few hours, to generate their own air-quality reports. Participants do not require previous training in programming or electronics, anyone interested in learning more about air quality and can participate, contributing data towards a creating a healthier city.

CanAirIO is based in Colombia and is managed by Cos4Cloud partner Trébola Organization, however the device can be built and used to generate air quality data locally, nationally, across Europe and internationally. The website associated documents and information are available in English and Spanish.

FreshWater Watch is a global citizen science platform that investigates the health of freshwater ecosystems globally thanks to participatory science. The main parameters measured are nitrates, phosphates, turbidity, bank vegetation, wildlife, pollution sources, water level, water speed, watercolour and presence of algae. It combines an online portal and a mobile app, where data collected can be viewed in real time.

[51] Source: CanAIrIO website: https://canair.io/
[52] Source: CanAIrIO website: https://canair.io/
[53] Source: CO Survey 2, December 2022

Freshwater Watch is used by individual researchers and local communities interested in monitoring the health of local freshwater resources (i.e. rivers, lakes, streams, ponds, wetlands and reservoirs). The data provided contributes to evidence needed to support efforts to improve water quality[54]. There are over 30,000 datasets available.

Freshwater is essential; we can't survive without it. As cities become increasingly industrialised, freshwater is under more and more pressure. Furthermore, over 8 million people don't have access to quality freshwater.[55] The first step to protect freshwater is to better manage freshwater ecosystems. In this context, FreshWater Watch aims to help monitor the quality of freshwater ecosystems all over the world through participatory science and collaborative work.

FreshWater Watch has created a global water-quality database to assess the health of freshwater ecosystems all over the world. Participation of citizens is needed to help gather this information on a global scale, so better laws and policies can be demanded to protect it.

The project was started in 2012 as an online scientific and engagement platform supporting 80 citizen observatories on six continents. Developed and funded by Cos4Cloud partner Earthwatch. FreshWater Watch is available in English, Spanish, French, Portuguese, Chinese, Swahili, Romanian and has local, national, European, and supports observations posted internationally.

iSPEX is an innovative way to monitor air and water quality by measuring aerosols and water colour using a mobile app and a small optical add-on containing a spectrometer and a polarizer. It is anticipated that citizens and scientists can use iSPEX to capture air and water quality observations and possibly more. The idea is based on the Spectropolarimeter for Planetary Exploration (SPEX), sized down to allow as many people as possible to use the instrument.[56]

The iSPEX device can be attached to any smartphone, giving users the power to collect and analyse data whether as part of a conducting a citizen science initiative or an interest in learning more. The app and add on were under further development as part of Cos4Cloud as well as upgrades to the add-on and sensor capabilities to monitor air and

[54] Source: : https://www.freshwaterwatch.org/.
[55] Source: https://cos4cloud-eosc.eu/citizen-science-innovation/cos4cloud-citizen-observatories/freshwater-watch/
[56] Source: https://cos4cloud-eosc.eu/citizen-science-innovation/cos4cloud-citizen-observatories/ispex/

water quality properties[57]. The iSPEX 2 add on, app and high-performance platform will be available here.

Earlier initiatives using iSPEX saw measurements by thousands of citizen scientists in the Netherlands using their smartphones and the add-on delivered accurate data on dust particles in the atmosphere that added valuable information to professional measurements[58] iSPEX was started in 2015 and was developed by Leiden University in the Netherlands and Cos4Cloud partner DDQ Pocket Science , who developed the software and hardware. It is available in Dutch and English and has geographical coverage locally, nationally, across Europe and internationally.

KdUINO was originally developed for the European project Citclops as a low cost open-source, monitoring system to measure water transparency. Citizens build their own buoy with its sensors and set it in the sea.[59]

Under CitClops KdUINO, was developed based on a low-cost photonic sensor and was successfully operated and the data collected validated comparing the measurements[60].It monitors water quality by leaving the KdUINO in the water for a long time. The buoy collects data on transparency, measured using the sensors on the KdUINO. It thus gives continuous transparency measurements in real time and provides coverage for a large coastal zone, something not possible using traditional radiometers due to their cost.

It was developed by Cos4Cloud Coordinator ICM-CSIC as part of the MONOCLE project. Within Cos4Cloud it was being upgraded to gather information on different colour bands (RGB). A do-it-yourself (DIY) version is also being developed that will have better usability, as well as being lighter weight and more portable.

Odour Collect is a citizen observatory to empower citizens to tackle odour pollution. Odour pollution is the second most frequent reason for environmental complaints in the world, after noise, and it can be a sign of greater environmental problems[61]. OdourCollect is available as a website and a free app that

[57] Source: https://ispex.org/
[58] Source: iSPEX project in EU-Citizen.Science: https://eu-citizen.science/project/81 .
[59] Source: https://cos4cloud-eosc.eu/citizen-science-innovation/cos4cloud-citizen-observatories/kduino/
[60] Bardaji, R., Sánchez, A. M., Simon, C., Wernand, M. R., & Piera, J. (2016). Estimating the underwater diffuse attenuation coefficient with a low-cost instrument: The KdUINO DIY buoy. Sensors, 16(3), 373.
[61] Source: https://cos4cloud-eosc.eu/citizen-science-innovation/cos4cloud-citizen-observatories/freshwater-watch/

aims to tackle odour pollution by empowering affected citizens to build collaborative odour maps. The app promotes a driving force of change, encouraging dialogue among citizens, local authorities, industries and experts.

Any citizen can act as an observer and report geo-localised observations on the odour episode, which are open data and can be used to build collaborative odour complaint maps and identify potential odour emitting sources. The best sensor to measure an odour is the human nose itself. To actively participate in science, users can download the OdourCollect app from the Apple Store, Android or check the website.

OdourCollect seeks to empower communities affected by odours[62]. Citizens from affected communities register their observations building collaborative maps and using meteorological models and identifies potential odour emitting sources[63]. Observations can be validated by experts to gather data in a particular area where a community is affected by odour pollution and with the aim of co-designing local solutions with relevant stakeholders.

The system can gather real-time data on odour perception anywhere, anytime, by any citizen. is under validation in 10 pilot projects in Spain, Chile, Greece, Portugal, Germany, UK, Bulgaria, Italy and Uganda and the aim is to develop the methodology for replication worldwide. It is used locally, nationally, across Europe and internationally and is available in Spanish, English, Catalan, Portuguese, German, Italian and Greek.[64]

OdourCollect was developed by Cos4Cloud partner Science for Change and was first developed under the European D-Noses project (Distributed Network for Odor Sensing, Empowerment and Sustainability) with a focus on co-creating alternative solutions to odour pollution.

4. Identifying CO best practice and assessing the impact of Cos4Cloud on COs

4.1 Cos4Cloud COs - citizen observatory surveys

To help gather information to better understand the role and context of the nine COs associated with the project, as well as assess the impact of Cos4Cloud *as an outreach methodology*, two surveys were conducted inviting all citizen observatories and DIY

[62] Source: https://odourcollect.eu/
[63] Source: CO Survey 1.June 2020
[64] Source: https://ispex.org/

initiatives (collectively referred to as COs) to participate. The surveys were developed as a structured way to gather common attributes and characteristics i.e. the aim, geographic scope, project duration, target groups, what they monitor, and type of data collected as well as how data is collected, interpreted, visualised disseminated and the technologies used to do.[65]

In addition to this the surveys were used as a mechanism to explore a range of characteristics[66] from the experiences of the COs themselves i.e.

- How CO's involve participants in environmental monitoring
- The range environmental phenomena targeted
- How COs involve and engage participants i.e. outreach, education and public awareness, etc
- The CO community and approaches used that facilitate this
- Identifying and evaluating impact and effectiveness of the CO

Cos4Cloud CO Survey 1 (June 2020)[67] focused on gathering information to find out more about the COs involved in Cos4Cloud, and better understand the needs and differences. Survey results also informed outreach, engagement and communications (i.e. information collated has also been used in project summaries of the COs; https://cos4cloud-eosc.eu/citizen-science-innovation/cos4cloud-citizen-observatories/); key strategic planning for co-design, networking, engagement, outreach, communication and dissemination, while gathering information on best practice to contribute towards capacity building for other COs. Information collected included:

- Introductory / general information: i.e. CO name, years in operation, objective, environmental discipline / theme, etc.
- Data collection: type of data, geographical focus, main locations of observations
- Technical information: programming language, protocols / standards; data management, storage and licences for data sharing
- Engagement: main user groups, types of use i.e. contributing to data, educational activities, research etc.; types and no. of users
- Testimonials, success stories collection / documentation, activities etc.
- Use of co-design
- Training and educational tools and resources
- Performance: i.e. metrics for data collection
- Use and impact, as well as lessons learned
- Governance

[65] Liu et al, 2014.
[66] Liu et al, 2014
[67] See Appendix 1 Citizen Observatory Survey 1, June 2020

- Lessons learned about: development of and use of user materials; technology; ensuring reliability; sustainability

Figure 2 Word Cloud key words CO Survey 1

Cos4Cloud CO Survey 2: (December 2022)[68], focused on capturing experiences i.e. actions, benefits, lessons learned etc. in Cos4Cloud from the perspectives of COs involved in the project. It gathered feedback, suggestions and comments about impact from the CO leaders that can help other COs make the best use of the project's outputs. It collected information towards building guidelines on how a CO can be enhanced and developed within a Cos4Cloud framework.

Information collated included:

- Involvement of CO in Cos4Cloud: i.e. integrating and testing services, educational activities with schools, other activities with COs, citizens scientists, other beneficiaries etc.
- CO benefits: i.e. technical development of platform infrastructure, contributions to data, quantity / quality of observations etc.
- Impact: i.e. on the CO user community, in the use of the CO, etc.
- Contributions to participation in COs: outreach and engagement initiatives to reach new or wider audiences; research etc.
- Best practices and outcomes: highlights from COs involvement in Cos4Cloud
- Lessons learned: i.e. technology (Cos4Coud Services).
- Recommendations and benefits for other COs: What works or doesn't work when creating or sustaining a CO.

[68] See Appendix 2 Citizen Observatory Survey 2, December 2022.

Figure 3 Word Cloud key terms CO Survey 2

5. Cos4Cloud CO best practice and the ECSA Ten Principles

The focus of this section of the report is to summarise, review and demonstrate best practice in citizen observatories through the experiences of COs directly involved in the project. In this context, best practice can be defined as a set of guidelines i.e. how to carry out a task, that if followed can result in good outcomes. The discussion highlights feedback from the CO surveys, demonstrating examples of CO best practice, reviewed using the ECSA Ten Principles as well as core CO attributes, characteristics and properties as a framework for analysis .

Core terms and themes identified were used to categorise relevant survey questions. Questionnaire responses gathered mainly from the CO Survey 1 and a some from CO Survey 2 have been categorised and the table below is a summary of the framework developed shaped by the ECSA Ten Principles.

Figure 4 Table 1: Ten Principles of Citizen Science: a framework for the collation of Cos4Cloud CO best practice experiences

ECSA - Ten Principles of Citizen Science *Key themes defining best practice highlighted in yellow*		**Identify CO best practice: topics and themes**
ECSA Principle[69]:	**Principle in practice: summary challenges / examples[70]**	**CO characteristics demonstrating best practice**
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.*	Ideas and examples of initiatives that can engage participants in person as well through digital technologies	- Purpose / role / objective - Type of data collected and contribution to research etc. - Timeline of operation / activity - Number of users - Geographic focus and languages
2. Citizen science projects have a genuine science outcome. *For example, answering a research question or informing conservation action, management decisions or environmental policy.*	It is more than education or outreach i.e. increased evidence of support for learning and research e.g. publications.	- Disciplinary field / topic - Type of data collected and purpose - Scientific and research contributions / outputs i.e. scientific publications, conferences etc.
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.*	Citizen science initiatives must benefit all involved to be sustainable. This can include scientific outcomes, social interaction, skills development, learning etc.	- Identify main groups that use the CO - Resources available (i.e. guidelines, tutorials, promo / info videos, leaflets, training courses/ webinars, etc. - Embedded quizzes educational / learning / training activities and how they facilitate involvement and participation of different user groups. - Engagement activities / strategies - Evidence / examples of involvement and participation of different user groups. Tools for engagement, outreach, education etc.

[69] ECSA, 2015
[70] Robinson, et al 2018

ECSA - Ten Principles of Citizen Science (cont'd) *Key themes defining best practice highlighted in yellow*		**Identify CO best practice: topics and themes**
ECSA Principle	**Principle in practice: summary challenges / examples**	**CO characteristics demonstrating best practice**
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*	The main method of engaging the public is contributory in which participants mainly contribute data. Others should be encouraged.	- How participants contribute / use COs - Methods of engagement i.e. activities - Evidence of impact – experiences and lessons learned
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.*	Different options can be used to provide feedback i.e. social media, websites, newsletters, events, blogs etc. Sharing feedback demonstrates and encourages participation.	- Different channels and tools used to give and receive participants feedback i.e. documenting user comments, collecting testimonials, stories etc from users. - Evidence / examples of different resources / tools for engagement, outreach, participation - Types of resources guidelines etc targeting different target groups
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.*	The validity & accuracy of citizen science data can be questioned, however data can be of equal quality.	- Contributions to research papers / publications., conferences etc - Use of the CO as a source of data or as a resource for scientific publications - Assuring validity and accuracy lessons to ensure this - How data is managed - Measuring performance and the metrics used to do so - activities / impact.
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.*	Projects and initiatives working towards open data.	- How data is collected - Data availability, how is it shared and managed i.e. open access - Licences used for sharing data - Ensuring data reliability – lessons learned - Examples that demonstrate how COs seek to do this via lessons learnt etc., lessons– that demonstrate it

ECSA - Ten Principles of Citizen Science (cont'd) *Key themes defining best practice highlighted in yellow*		**Identify CO best practice: topics and themes**
ECSA Principle	**Principle in practice: summary challenges / examples**	**CO characteristics demonstrating best practice**
8. Citizen scientists are acknowledged in project results and publications.	Recognition of citizen scientists contributions via project, communication, user badges etc.	- How user contributions are acknowledged / recognised - Data use as a resource for scientific publications
9. Citizen science programmes are evaluated for their scientific output, data quality, participant experience and wider societal or policy impact.	Evaluation is not always possible. Therefore, despite this, outcomes, which can be valuable, are sometimes not fully documented or reported.	- Documenting success stories - Impact of the data i.e. policy, social, environmental, etc. - How is the CO used / what are the types of contributions made? i.e. to education, policy, public engagement, participation i.e. PES, PPSR, etc.
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.	Considering ethical matters is an important part of citizen science activities which involve people volunteering their time.	- How privacy is managed, and data shared - Terms and conditions around copyright, intellectual property, data sharing agreements, confidentiality, attribution, etc.

5.1 Analysis of Cos4Cloud CO experiences: Thematic summary of characteristics and experiences as demonstrators of best practice

The following section presents information about the COs in Cos4Cloud using themes guided by the ECSA Ten Principles . Using this as a framework allows for a discussion that emphasises core citizen science related themes and terms in the context of other COs. Results from CO Survey 1 and CO Survey 2 have been mapped to contribute to the discussion around themes from each Principle.

Firstly, key terms identified within each of the ECSA Ten Principles, were used to guide the collation if survey responses and the questions asked. Using this as a framework examples of CO experience were collated to further demonstrate examples of best practice .

Using the table above as a guiding framework, the information presented below is structured as 10 themes summarising characteristics and experiences of best practice. The results documented below contributes to a targeted Cos4Cloud outreach (and engagement) methodology. This is being further consolidated into guidelines of best practice, targeting other COs, associated stakeholders, etc., and made accessible through the ***Cos4Cloud Toolbox and Evidence Hub*** is part of Cos4Cloud's knowledge transfer.

Thematic summary of characteristics and experiences demonstrating CO best practice

5.1.1 Theme 1: COs "use digital technologies" to "actively involve citizens in scientific endeavours that generate new knowledge or understanding"

ECSA Principle 1[71]:	**Principle in practice: summary challenges / examples[72]**	**CO characteristics demonstrating best practice**
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.*	Ideas and examples of initiatives that can engage participants in person as well through digital technologies	- Purpose / role / objective - Type of data collected and contribution to research etc. - Timeline of operation / activity - Number of users - Geographic focus and languages
Cos4Cloud COs best practice characteristics: Theme1: COs use digital technologies to actively involve citizens. A clearly outlined purpose / objective, framed by the environmental or scientific topic, defines the type of observations that are contributed, and the type of data collected. The defined geographic focus and languages available contribute to how this can be communicated to "engage participants". Evidence of involvement can be tracked over time through user participation and this activity demonstrates examples of the role citizens play "in scientific endeavour that generate new knowledge or understanding".		

A common feature of COs is the use of digital technologies and the COs in Cos4Cloud each have clearly outlined and expressed objectives and a defined purpose engaging different target groups. Documenting observations within specified fields / disciplines / topics they are collecting geographically located data that over time can inform understanding of these topics while generating new knowledge.

[71] ECSA, 2015
[72] Robinson, et al, 2018

For example, with a focus on biodiversity monitoring, **Artportalen** is a reporting system for species observations and data collection focused on Sweden's natural history. **iSpotnature** was developed to encourage and support people to record and learn about wildlife as well as how to identify and **Natusfera** shares biodiversity learning with its community while **Pl@ntNet** monitors plant biodiversity and facilitates access to plant knowledge. While focusing on environmental monitoring **CanAirIO** creates and develops manuals for building DIY devices for citizen science; **FreshWater Watch** monitors water quality; **iSPEX** measures aerosols with a spectropolarimeter add on and **OdourCollect** builds collaborative maps to tackle odour pollution issues.

Summary information about the scope and role of the COs provides useful context such as timeline of operation, number of users, geographical focus; countries where observations are mostly from, and languages supported etc. as well as understanding of the geographical focus and range of audiences is an important part of defining the scope for user engagement, outreach and communications tools and resources to "actively involve citizens"[73].Further details summarised by the COs from the survey responses are in the table below.

Cos4Cloud COs: examples of information and activity demonstrating best practice[74]:						
CO	**Years / timeline the CO has been operating**	**CO Geographic focus**	**Countries where observations are mostly from**	**Language the CO supports**	**Main objective the CO seeks to fulfil**	**Number of users**
Artportalen	Launched: 2000 22 years	National	Sweden	Swedish	Reporting system for species observations, community for users, data collection and delivery to environmental managers and researchers, education concerning Sweden's natural history	Over 40 000 unique monthly visitors, about 1 000 users contribute 85% of the observations.

[73] ECSA, 2015
[74] Sources: Cos4Cloud CO Surveys 1 (June 2020) and 2 (December 2022).

CO	Years / timeline the CO has been operating	CO Geographic focus	Countries where observations are mostly from	Languages the CO supports	Main objective the CO seeks to fulfil	Number of users
iSpot	Launched 2009: 13 years	Local, National, European, International	UK and Ireland	English	iSpotnature is an online citizen science platform for biodiversity that was developed to encourage and support people to record and learn about wildlife as well as how to identify it.	over 80,000 registered users
Natusfera	Launched 2016: 6 years	Allows the creation of dedicated projects allowing all types of geographical scope	Spain	English, Spanish, Catalan, Galician, Euskera, Italian	Sharing biodiversity learning with all the community	more than 20,000
Pl@ntNet	Launched 2011: 12 years	International	France, Germany, US, Italy, UK, Netherlands, Spain, Brazil, Belgium, Switzerland	French, English	Monitoring plant biodiversity and facilitating access to plant knowledge by the general public	4 million user accounts + 20 million anonymous end-users)
CanAirIO	Launched 2018: 4 years	Local, National, European, International	Colombia	Spanish / English	Creating and develop manuals for the building DIY devices for Citizen Science	Users with fixed stations: 25; Mobile users 400;
Fresh Water Watch	Launched 2012: 10 years	International	UK, US, Tanzania	English, Spanish, French, Portuguese, Chinese	Monitoring water quality	30,000
iSPEX	Launched 2015: 7 years	National	Netherlands	Dutch	Measuring aerosols with a spectropolarimeter add on	(10.000 in 2014) Currently researchers only

CO	Years / timeline the CO has been operating	CO Geographic focus	Countries where observations are mostly from	Languages the CO supports	Main objective the CO seeks to fulfil	Number of users
Odour Collect	Launched 2015 - 2016: 6 - 7 years	Local, National, European, International	Spain, Chile, Greece, Portugal, Germany, UK, Bulgaria, Italy and Uganda.	Spanish, English, Catalan, Portuguese, German, Italy, Greek.	Builds collaborative maps to tackle odour pollution issues. Citizens from affected communities register their observations to build these maps and, through meteorological models, OC identifies potential odour emitting sources.	1200

5.1.2 Theme 2: COs contribute to research that can achieve a "science outcome", supporting "learning and research" while facilitating participation, engagement and outreach

ECSA Principle 2[75]:	Principle in practice: summary challenges / examples	CO characteristics demonstrating best practice
Citizen science projects have a genuine science outcome. *For example, answering a research question or informing conservation action, management decisions or environmental policy.*	It is more than education or outreach i.e. increased evidence of support for learning and research e.g. publications.	- Disciplinary field / topic - Type of data collected and purpose - Scientific and research contributions / outputs i.e. scientific publications, conferences etc.
Cos4Cloud COs best practice characteristics: Theme 2: Users contribute observations to COs through established protocols based on the scientific discipline / field. This provides data which is made available as a source for research i.e. scientific publications etc., that can achieve a science outcome. This also supports education and learning while facilitating participation, engagement and outreach.		

[75] ECSA, 2015

The Cos4Cloud COs collect observations within specified protocols, and this presents data that contribute to research i.e. real science outcomes. For most, this has been presented at conferences etc and cited in scientific publications in different ways. For example, with **Artportalen** this can be cited as data originating from the CO platform itself, its affiliate Swedish LifeWatch or as a data download available on GBIF. With **iSpot**, members of the team have been either co-authors and or lead authors on some papers using iSpot data; in some, iSpot is cited as a source; while in others iSpot is consulted and the use of the platform itself and data acknowledged.

Pl@ntNet has some similarities to iSpot: some papers have been co-authored with the team; some articles cite these publications by the team (in particular the ones about LifeCLEF challenges that regularly use Pl@ntNet data). While others cite Pl@ntNet in the acknowledgements or in the main text. For **OdourCollect**, many members of the affiliated D-Noses project have been cited and acknowledged in publications, both as authors and/or collaborators and **iSPEX** data has been cited in papers written by Leiden University, a lead partner.

For the COs, many published papers, citing the CO, can be found through online searches and some collate information about publications in a managed list which is sometimes made available. For others who provide data via GBIF the use of CO data sourced is also cited via the GBIF platform.

Cos4Cloud COs: examples of information and activity demonstrating best practice:				
CO	**Disciplinary fields/topics the CO is active in**	**Type of data does the CO collects**	**Has your CO been used as a source of data or as a resource for a scientific publication?**	**Have insights generated by your CO been used for policy-making or similar activities?**
Artportalen	Biodiversity	Biological records, Coordinates, Photos, Sounds, Video	Yes	Yes
iSpot	Biodiversity	Biological records, Coordinates, Photos	Yes	Yes.
Natusfera	Biodiversity	Coordinates, Photos, Sounds, Validation information from other members	Yes	No
PlantNet	Biodiversity	Biological records, Coordinates, Photos	Yes	No

CO	Disciplinary fields/topics the CO is active in	Type of data does the CO collects	Has your CO been used as a source of data or as a resource for a scientific publication?	29. Have insights generated by your CO been used for policy-making or similar activities?
CanAirIO	Air quality	PM 2.5 values, PM 1.0, PM10, Humidity, Temperature, Geo Localisation, Gas resistance, Altitude, Pressure	No	Yes
Fresh Water Watch	Water quality	Coordinates, Phosphate, nitrate, turbidity	Yes	Yes
ISPEX	Air quality, Water quality	PM 2.5 values, Coordinates, Photos	Yes	Not formally
OdourCollect	Air quality, odour issues	citizens´ observations of odours	Yes	Yes

5.1.3 Theme 3: COs involve a range of groups who "benefit from taking part" in different ways i.e. "scientific outcomes, social interaction, skills development, learning etc "

ECSA Principle 3[76]:	Principle in practice: summary challenges / examples	CO characteristics demonstrating best practice
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.*	Citizen science initiatives must benefit all involved to be sustainable this can include scientific outcomes, social interaction, skills development, learning etc..	- Identify main groups that use the CO - Resources available (i.e. guidelines, tutorials, promo / info videos, leaflets, training courses/ webinars, etc. - Embedded quizzes educational / learning / training activities and how they facilitate involvement and participation of different user groups .

[76] ECSA, 2015

		- Engagement activities / strategies - Evidence / examples of involvement and participation of different user groups. Tools for engagement, outreach, education etc.
Cos4Cloud COs best practice characteristics: Theme 3: COs involve professional scientists, experts citizen scientists and a range of other different groups and all can "benefit from taking part" in different ways i.e. research outputs, contributing to scientific evidence, learning opportunities, skills development, personal enjoyment, etc. A range of educational, engagement and outreach tools and resources are also developed and disseminated which support participation.		

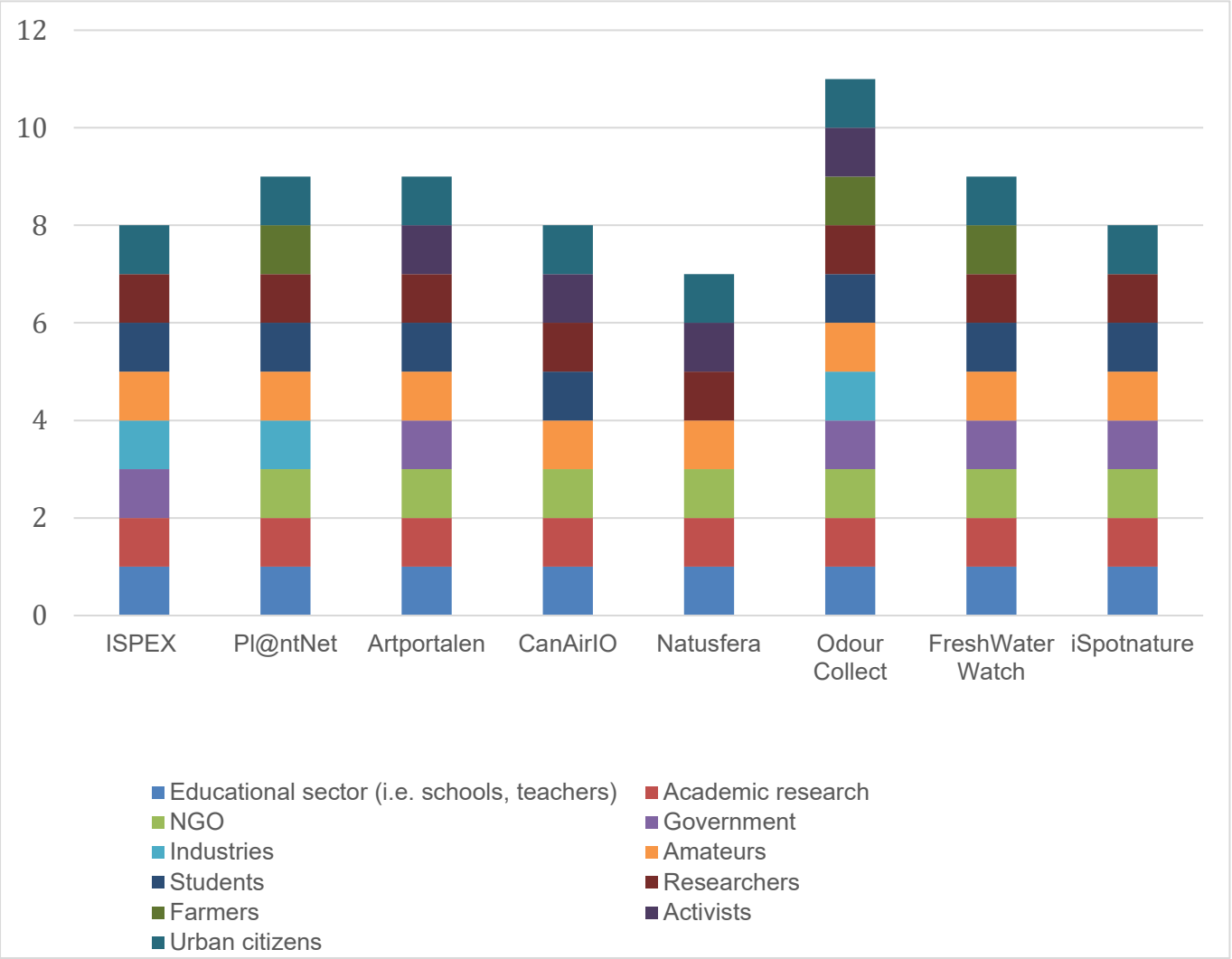
The Cos4Cloud COs engage with a range of stakeholder groups who have a variety of reasons or motivations for use (i.e. contributing to data, use for educational activities, creating research, among others) and based on this benefit from taking part in different ways. The COs were asked to describe the main groups involved from a list of possibilities including: the educational sector (i.e. schools, teachers), academic researchers, NGOs, Government, industries, amateurs, students, researchers, farmers, activists, urban citizens, others.

Cos4Cloud COs: examples of information and activity demonstrating best practice:

Part of the sustainability of COs is dependent on implementing measures to help facilitate continued engagement; this includes engagement and outreach and resources (i.e. set of guidelines, tutorials, promo / info videos, leaflets, training courses/ webinar etc) targeting these different groups. For example **Artportalen** has created webinars, pdf instruction manuals and online help topics (https://help.artdatabanken.se/selfservice#a3ca39bd-e06e-424c-9f46-35b471bba3ba).

With **iSpot,** engagement and outreach are wide ranging, and the team has created and collaborated on different flyers and resources targeted at different audiences. Some have been developed linked with OU/ BBC co-productions. Some webinars have been hosted and videos created, and these are embedded and available from the iSpot website help and support. There is also guidance on the iSpot user experience i.e. explore, record, collaborate, learn, learn and what it is about. **Natusfera** has created several online resources, specific guides are available here.

Figure 5 What are the main groups that use the CO?



Pl@ntNet has also developed a range of resources in different formats and languages. These include Youtube video produced by Inria's multimedia service explaining the principle of Pl@ntNet. There are also tutorials about how to use the Pl@ntNet app. As well as a selection of tutorial videos produced by the Pl@ntNet user community in different languages, examples include: Nommer une plante grâce à l'application Pl@ntnet (french), Tuto Pl@ntnet (french), Un outil GRATUIT d'aide à l'identification du nom des plantes par l'image | Découvrir la nature (french), Vorstellung Pl@net App - Pflanzen Bestimmungs-App (german), Como usar Plantnet (spanish). ThePlantGame is a smart quizzes game developed by Pl@ntNet, and a tutorial has been created supporting this french). Documents and resources (i.e. slides or printable resources) created as examples of activities with scholars: and the Pl@ntNet FAQs also provide support.

CanAirIO has a range of different resources including how to create the DIY device: as well as other support videos including: CanAirIO Net; Encuentro virtual Red Ciudadana de Calidad del Aire CanAirIO;, activities with SciStarter: and a Github repository. **FreshWater Watch** hosts training videos and an online quiz. They also run training workshops and train the trainer sessions. iSPEX resources were previously developed but that website is no longer maintained. OdourCollect has a selection of tools and resources to engage and train participants: webinars, face to face/ online workshops, sensory walks to recognize odours, leaflets, flyers, a video, training courses (MOOC) and conferences.

5.1.4 Theme 4: COs provide a platform where users can "participate in multiple stages" of research

ECSA Principle 4[77]:	**Principle in practice: summary challenges / examples**	**CO characteristics demonstrating best practice**
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*	The main method of engaging the public is contributory in which participants mainly contribute data. others should be encouraged.	- How participants contribute / use COs - Methods of engagement i.e. activities - Evidence of impact, experiences and lessons learned
Cos4Cloud COs best practice characteristics: Theme 4: Participation in citizen science initiatives is defined by different typologies that can involve multiple stages. COs also facilitate engagement in different ways including crowdsourcing, validating or confirming identification of observations; as well as through social interaction which also facilitate a process of feedback This supports collaboration i.e. through collaborative and personalised approaches and co-creation through the use of integrated tools or creating DIY devices . Lessons learned demonstrate impact in terms of participation in different levels and multiple stages of the scientific process.		

Citizen science supports anyone to get involved with scientific research and is recognised as a means towards public participation and engagement with science. Citizen scientists are seen to generally participate through a range of typologies and different stages of the scientific process i.e. contributory, collaborative and co-created initiatives.[78] i). contributory - designed by scientists, public contribution of data ; ii) .collaborative - designed by scientists, public contributes data and helps refine, design, analyse data and

[77] ECSA, 2015

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

/ or disseminate findings and iii). co-created - designed by scientists and members of the public working together some participants are actively involved in most or all steps [79]. With other frameworks emerging it has been suggested that participation in COs occurs through different stages or levels of participation[80] : crowdsourcing (i.e. citizens inputting observations as sensors); distributed intelligence (citizens providing more input i.e. validation which can be supported by training offered through web-based resources); participatory citizen science which engages participants in additional steps collecting, analysing as well as think of research questions; and finally collaborative or 'extreme citizen science which provides integration at all levels[81]

Cos4Cloud COs: examples of information and activity demonstrating best practice:

Approaches and user cases demonstrating different levels of participation

As noted above COs provide a platform where users can be involved in different ways encouraging "the participation of citizens in data collection, data interpretation and information delivery" using an ICT infrastructure[82] In addition to this COs provide different types of opportunities or roles for participation as makers (i.e. developing Do-it-Yourself tools) , observers (i.e. use the technology available to provide observations) or analysers (i.e. interpreting or validating information).[83]

For **Artportalen** this includes user contributions that inform environmental planning, decision making, research, impact assessments, Flora and Fauna Guardians, annual and status reports**. iSpot** is used in bioblitzes, biodiversity monitoring, published atlases of groups of organisms such as mammals, contributes to national reports i.e. State of Nature; analysis and reporting of different species groups etc.

On **Natusfera** users participate in bioblitzes, monitoring phenology, monitoring fauna, creating their own projects (for specific purposes). With **Pl@ntNet** this involves recreational and professional usage of the Pl@ntNet App - as well as educational programs workshops/training (i.e. the Telabotanica MOOC) and various bioblitzes. **CanAirIO** supports users with air quality monitoring while FreshWater Watch facilitates monitoring, stewardship, education, and informing policy.

[79] Bonney, R., Ballard, H., Jordan, R., Mccallie, E., Phillips, T., SHIRK, J., Wilderman, C. C. (2009) Public Participation in Scientific Research: Defining the Field and Assessing Its Potential for Informal Science Education. A CAISE Inquiry Group Report. Online submission.

[80] Haklay, M., 2013, Citizen Science and Volunteered Geographic Information – overview and typology of participation in Sui, D.Z., Elwood, S. and M.F. Goodchild (eds.), 2013. Crowdsourcing Geographic Knowledge: Volunteered Geographic Information (VGI) in Theory and Practice . Berlin: Springer. pp 105-122 DOI: 10.1007/978-94-007-4587-2_7

[81] Ibid.

[82] Liu et al, 2017.

[83] Monimo et al., 2017

iSPEX devices help users measure the polarisation of light to study air quality, and monitors water quality to detect the presence of certain particles or substances in the water, (i.e. algae, bacteria, or pollution). While **OdourCollect** is used to register observations regarding odours affecting where people live, allowing them to participate in research that impacts on their lives.

Engagement tools that facilitate different levels of participation contributing to involvement in the scientific process

Supporting the levels of participation noted above, some of the COs involved in Cos4Cloud offer tools that support different types of engagement (i.e. embedded quizzes etc) and educational / learning activities with schools, universities, and any forms of informal learning and training; supported by feedback and social interaction.

iSpot has automatically generated quizzes (www.ispotnature.org/quiz) that are freely available to users. Any of the main groups of organisms (plants, animals, birds etc) and level of difficulty can be selected , then the system automatically generates a quiz. An almost infinite number of different quizzes can be automatically produced using the database of observations and images. iSpot also has integrated tools to support building ID skills. These include online keys (www.ispotnature.org/communities/uk-and-ireland/view/article/8264/ispot-keys-for-identifying-wildlife) and the iSpot species browser: www.ispotnature.org/communities/uk-and-ireland/species-browser).

A core aim of iSpot is learning and teaching and iSpot has been integrated as an education tool into OU formal courses (i.e.S295 - Biology of Survival; E209 - Developing subject knowledge for the primary years). It has also been integrated into free courses (i.e. Citizen Science and global biodiversity and Introduction to Ecosystems and other free learning resources available on OpenLearn (https://www.open.edu/openlearn/).

In addition to **Pl@ntNet** apps, there are other other tools: the Floris'Tic program, a French educational program co-organized with TelaBotabnica NGO and Agropolis Foundation. Other examples are smart quizzes, ThePlantGame developed by Pl@ntNet and used in the context of the TelaBotanica MOOC platform; and Smart'Flore app which allows participants to browse botanical trails created collaboratively (see e.g. in this video). Other examples include resources created for activities with scholars (e.g. the Floris'Tic program).

CanAirIO additional tools and resources includes: The Breathe Natural project: Proyecto Jaboque - Respira natural; workshop: Environmental month focus on Air Quality: Mes ambiental de la calidad del aire - Colsubsidio and the project: Aulas vivas comunitarias - Barrio Marandú.

OdourCollect has a MOOC on Odour pollution and also specific material for schools, which have been used in Uganda and Spain.

CO	Lessons learned from developing materials (i.e. tutorials, guidelines etc) to facilitate use of the CO i.e. different use cases (eg. BioBlitzes, monitoring phenology, monitoring fauna, IUCN[84] Red list assessment etc)
Artportalen	Not to underestimate the amount of effort required to ensure that resources are up-to-date and that they include all changes to the platform.
iSpot	Having a range of resources available to support different ways it is used. iSpot has combined teaching/learning and research, contributing formal and informal learning at the OU and other institutions. It is used by groups, schools and colleges as well as by the general public of all ages and abilities; users include a rapidly expanding community of experts, children of dozens of schools and universities and tens of thousands of members of the general public.
Natusfera	Should be shared in open formats to be reused and improved through time.
Pl@ntNet	Visual materials attract much more attention- people don't read textbooks- people love tutorials and youtube videos. Gamification such as puzzles and treasure hunts work very well with students whatever the age
CanAirIO	Difficulties doing the DIY devices from our guides was highlighted. The acquisition issues for buying the materials or components from our guides.
Fresh Water Watch	Need to adapt to the audience
OdourCollect	Keep it simple: simple videos and how-to tools are the most effective.

[84] International Union for Conservation of Nature (IUCN)

5.1.5 Theme 5: COs involve users and provide "feedback" as part of the process of engagement and participation

ECSA Principle 5[85]::	Principle in practice: summary challenges / examples	CO characteristics demonstrating best practice
Citizen scientists receive feedback from the project. *For example, how their data are being used and what the research, policy or societal outcomes are.*	Different options can be used to provide feedback i.e. social media, websites, newsletters, events, blogs etc. Sharing feedback demonstrates and encourages participation	- Different channels and tools used to give and receive participants feedback i.e. documenting user comments, collecting testimonials, stories etc from users . - Evidence / examples of different resources / tools for engagement, outreach, participation - Types of resources guidelines etc targeting different target groups
Cos4Cloud COs best practice characteristics: Theme 5: CO user involvement is supported and encouraged through both giving and receiving feedback to and from users. Options for users to provide this is an important part of the participatory process also. For example many COs, particularly those focussed on biodiversity, feedback as validation agreement etc is part of the crowdsourcing of identifications within the community as part of the ID process. However, more structured public feedback is integrated as part of engagement and outreach i.e. news, social media etc.		
Cos4Cloud COs: examples of information and activity demonstrating best practice:		

COs allow open exploration of the observations and data available on the platform using the tools and features available. Registration is an important part of this process as it gives participants access to post observations, add comments, participate in forum discussions etc. In terms of feedback from the CO this can be publicly available provided in bespoke news sections of the CO platform as well as regular updates on activities as via social media. Feedback is provided in different ways, for example, in **Artportalen** this is reflected in how data is used i.e. environmental planning, decision making and published scientific articles.

Some COs also provide dynamic participatory feedback processes. For example on **iSpot** the user community and CO team can communicate via iForum Live synchronous chat discussions. In **Natusfera** users have a dedicated blog service, where they can write their opinions that are available to the rest of the community. Success stories and testimonials are sometimes shared by the users themselves as part of the process of posting an

[85] ECSA, 2015

observation and one way of alternative ways COs provide feedback by collating and sharing these testimonials and user stories. On occasion these are also shared for CO promotions and publicity matters, and some are collated for project reports and a few publications. Where testimonials are not publicly available, permission is requested for wider use.

For example on **iSpot** testimonials are sometimes volunteered by users, posted as comments on an observation or via iSpot Forum post these are sometimes collated and shared with the wider community as examples of best practice which makes them more widely available. While **OdourCollect** has created videos of testimonials, through the D-NOSES project.

Figure 6 Collecting and documenting testimonials from active users

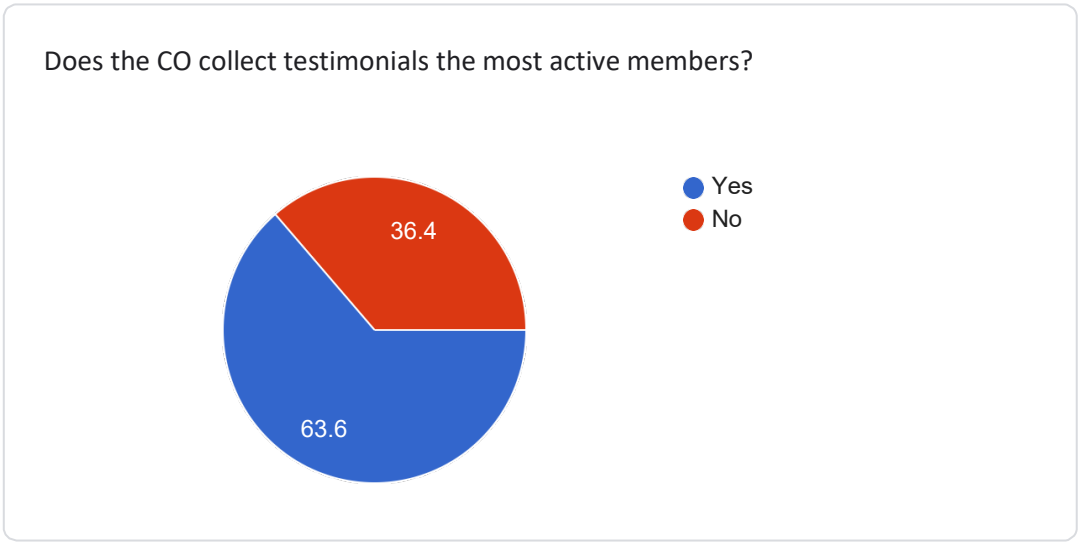
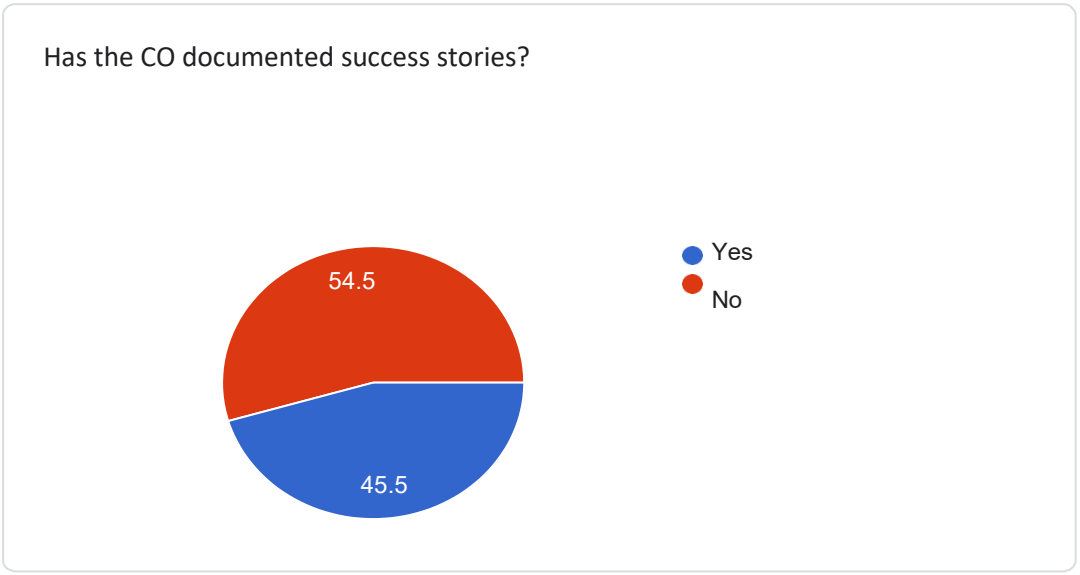


Figure 7 CO Collecting and documenting user success stories



Direct collation of success stories and testimonials is sometimes done for the more active users, but not by all the COs in Cos4Cloud, however most of the COs indicated interest in finding ways to collect and share these as part of their user feedback process.

5.1.6 Theme 6: COs are an important part of the citizen science scene. They make contributions as research infrastructures therefore similar control of "limitations and biases" apply

ECSA Principle 6[86]::	**Principle in practice: summary challenges / examples**	**CO characteristics demonstrating best practice**
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.*	The validity & accuracy of citizen science data can be questioned, however data can be of equal quality.	- Contributions to research papers / publications., conferences etc - Use of the CO as a source of data or as a resource for scientific publications - Assuring validity and accuracy – lessons learned to assure this - How data is managed - Measuring performance and the metrics used to do so - activities / impact
Cos4Cloud COs best practice characteristics: Theme 6: COs are an important part of the citizen science scene. They make contributions as research infrastructures therefore similar control of "limitations and biases" apply. Data management is a core consideration to ensure that relevant guidance and measures are implemented to reduce possibilities for errors and bias as well as increase the validity and accuracy of citizen science data.		
Cos4Cloud COs: examples of information and activity demonstrating best practice:		

Data management is a core consideration to ensure that relevant guidance and measures are implemented to reduce possibilities for errors and bias. Validity and accuracy of data and how this can be assured were a key consideration for the COs in Cos4Cloud in terms of considering the main lessons learned in terms of ensuring reliability and what works or doesn't towards ensuring trustworthy data and information.

According to **Artportalen** this requires "adequate 24/7 IT support to maintain a system people can rely on. Another factor is trust, therefore ensuring that sensitive species are hidden in the system and only available to those with appropriate access rights, for example, is very important for user trust. An extensive network of expert validators as well as automated 'likelyhood' rules are also important for users' trust in data quality. The

[86] ECSA , 2015

open data concept and that all users can comment on each other's observations along with 'no anonymous' reporting has also been found to be critical." [87]

The **iSpot** team highlighted similar points emphasising that an important factor for that CO is having a unique reputation system integrated. This demonstrates a system of verification of observations which is important in biological recording data. Some of the users on iSpot also run projects to check data quality of existing data, for example reviewing all the observations of sets of species and checking the ID's are correct. This not only increases data quality but is also a learning opportunity for the iSpot participants involved as they view large numbers of the same small set of species so they learn the key differences between them.

From the perspective of **Pl@ntNet** it is necessary to have a clean data model and an efficient database structure, the data acquisition step is crucial to improving data quality. "If your acquisition module is not restrictive enough, you may collect too much noise. In this regard, automatically rejecting unappropriated content is efficient." [88] It was noted that with a smaller percentage of observations revised for accuracy due to the skill sets in botany required, it is necessary to have an estimation of the skill level of each contributor to help assess data quality. However on Pl@ntNet "the vast majority of contributors are outperformed by AI algorithms in terms of plant identification performance - the collected data is always of heterogeneous quality and data post-filtering is always necessary."[89]

From the **Natusfera** experience, these types of data quality methods should be recognised. More actions are needed to convince the validity of the data from COs and that it should be exploited either for academic or management actions. **CanAirIO** is supported by academics who validate the data, as well as good infrastructure with open source and open data standards; while **FreshWater** Watch emphasises the importance of "keeping the method simple, being aware of bias"[90]; and **OdourCollect** noted that "transparency and open data fosters trust."[91]

[87] Artpotalen, CO Survey 1, June 2020.
[88] Pl@ntNet, CO Survey 1, June 2020
[89] Pl@ntNet, CO Survey 1, June 2020
[90] FreshWater Watch, CO Survey 1, June 2020
[91] OdourCollect, Co Survey 1, June 2020

5.1.7 Theme 7: COs promote "open data" and "metadata" practices while ensuring that data is accessible and "publicly available".

ECSA Principle 7[92]::	Principle in practice: summary challenges / examples	CO characteristics demonstrating best practice
Citizen science project data and metadata 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.*	Projects and initiatives working towards open data.	- How data is collected - Data availability, how is it shared and managed i.e. open access - Licences used for sharing data - Examples that demonstrate how COs seek to do this
Cos4Cloud COs best practice characteristics: Theme 7: COs promote open data and work together on metadata practices while ensuring that data is accessible and publicly available. CO data is made available using web-based applications and technology. How COs manage data as well as the licences used for sharing are also key.		
Cos4Cloud COs: examples of information and activity demonstrating best practice:		

COs promote open data and work together on metadata practices and principles while ensuring that data is accessible and publicly available. For COs, ensuring data is made available using web-based applications and technology is a core characteristic and part of how they are designed and implemented. Many implement data management plans governed by GDPR and have outlined process that governs the storage of data governed by CO management. For example **Artportalen** this is held with the Swedish University of Agricultural Sciences (SLU), where it was developed and is maintained by SLU Swedish Species Information Centre. **iSpot** was developed and is managed by The Open University, Milton Keynes, UK which hosts the servers where data is stored.

Natusfera is managed by a consortium of organizations, among them three Cos4Cloud partners: Bineo, CSIC and CREAF, and used cloud-based server infrastructure. **Pl@ntNet** is an open consortium that includes four French research organisms (CIRAD, INRAE, Inria, and IRD) and the Agropolis Foundation. CO data is stored using infrastructures in Montpellier, France (i.e. CIRAD DSI, Meso@LR, Inria)

How the Cos4Cloud COs manage and share data is mostly outlined in the CO user terms and conditions and use can vary based on the type of data collected (i.e. whether images

[92] ECSA , 2015

are included) and use for research purposes . For example, **Artpotalen** facilitates open data, but image copyright lies with the reporter. The creation of **iSpot** content (except images) which includes the use and collection of iSpot data are governed by the iSpot Terms of Use and Privacy Policy. The specific licence that iSpot uses is CC BY-NC 4.0. While on **Natusfera** users can choose among different options, from private to CC and **OdourCollect** facilitates open data for citizens observations

5.1.8 Theme 8: COs have built in "recognition" systems which acknowledge user contributions and communicate results from the user community

ECSA Principle 8[93]::	**Principle in practice: summary challenges / examples**	**CO characteristics demonstrating best practice**
Citizen scientists are acknowledged in project results and publications.	Recognition of citizen scientists contributions via project, communication, user badges etc.	- How user contributions are acknowledged / recognised - Metrics used to monitor and measure results as user and contributions
Cos4Cloud COs best practice characteristics: Theme 8: COs have built in recognition systems i.e. user badges, which acknowledge and recognise their contributions. User observations and other metrics are recorded, monitored and tracked using different tools. Information and results are communicated acknowledging the user community in publications etc.		
Cos4Cloud COs: examples of information and activity demonstrating best practice:		

COs have built in recognition systems which are mechanisms to manage and acknowledge contributors. For example on **Artportalen** all data is open with the exception of observations concerning sensitive species that are hidden within the system and only visible to the reporter and those with appropriate access privileges; no data is anonymous.

iSpot has an integrated 'reputation management' system which provides user-feedback on likely identifications, as users enhance their own identification skills. Users are badged depending on the level of reputation they have gained and which recording schemes they represent, This information is available on their public profile and on every interaction they have with an observation. The platform is supported by a curator who helps to provide oversight of an active online community. Participants can acknowledge support from others through the comments and forums.

[93] ECSA, 2015

On **Pl@ntNet** app performance is continuously improved thanks to the contributions of users (new species, new training data, revised quality, etc.). In return, contributors benefit from an improved performance tool. Feedback to contributors is provided through the website and social media. Also, a CC-by-SA licence ensures attribution to contributors wherever their data is used.

Natusfera has general dashboards on the platform which show user contributions and **OdourCollect** acknowledges the most active users with publicly recognised gold-silver medals and incentives. COs also acknowledge contributors in publications (anonymously) i.e. **FreshWater Watch** and **iSPEX.** For the COs user observations and other metrics are recorded, monitored and tracked using different tools.

CO	**Options used to collect metrics (i.e. Google analytics)?**	**Types of metrics collected to measure performance/activities/impact (i.e. no. of participants, recognition of contributions**
Artportalen	Google, New Relic, Summera, Easit, DevOps	Performance indicators reported including number of new observations, total number of species, total number of validated observations.
iSpot	Internal iSpot administration system and Google analytics	iSpot metrics are collated in two ways: 1. From the website admin pages Categories include: iSpot usage data: i.e. number of registered users, observations, determinations, agreements, images, average registrations per day , registered users who have added an observation, determination and agreement. Information about engagement i.e. how users hear about iSpot; observations per month for each species group; iSpot quiz, projects and other admin statistics. 2. Google Analytics: User sessions, no of users, pageviews, pages / sessions, average session duration, new vs returning users.
Natusfera	Internally recorded	Number of participants, number of observations, number of species
Pl@ntNet	Internally developed tools for server monitoring, Google analytics for app usage, Google news for press coverage, Google scholar for citations, App stores	Pl@ntNet internal statistics: https://identify.plantnet.org/stats Internally developed tools on top of ArangoDB, Monit & Munin for server monitoring- Google analytics for app usage Google news for press coverage Google scholar for citations App stores statistics

	statistics, social media statistics	Social media statistics. An Impact study[94] was done surveying a large panel (several hundred) Pl@ntnet users among the ones who created a user profile. We completed this survey with a usage analysis (based on google analytics tools) and several focus groups and interviews with representatives from different domains: (i) scientific field (ecology, computer science) and citizen science, (ii) agriculture, (iii) biodiversity management, (iv) education.
CanAirIO	Google Play analytics Google analytics Twitter analytics	Users, devices deployed, data collected, map coverage, news or policies from government of main topic
Fresh Water Watch	Collected by platform (participant numbers etc.), publications through internal mechanism	Impact tracker
iSPEX	Database entries	Number of signups/orders
OdourCollect	Through the web/mobile app Odour Collect	Number of people trained, number of participants, number of observations, number of active users, type of observations, intensity of odours, hedonic tone

[94] See Pl@ntNet Impact Study box in 5.1.9.

5.1.9 Theme 9: CO's conduct "evaluation" in different ways: studies on impact, use of data as a "scientific output", etc; experiences and stories are also sometimes documented towards understanding "wider societal or policy impact"

ECSA Principle 9[95]::	**Principle in practice: summary challenges / examples**	**CO characteristics demonstrating best practice**
Citizen science programmes are evaluated for their scientific output, data quality, participant experience and wider societal or policy impact.	Evaluation is not always possible therefore, despite outcomes, which can be valuable, are sometimes not fully documented or reported.	- Documenting success stories - Impact of the data i.e. policy, social, environmental, etc. - How the CO is used / types of contributions made i.e. to education, policy, public engagement, participation i.e. PPSR, etc.
Cos4Cloud COs best practice characteristics: Theme 9:: CO's conduct "evaluation" documenting outcomes in different ways: studies on impact, use of data, etc. Engagement and participation experiences and stories are also sometimes documented as user cases towards understanding and communicating "wider societal or policy impact".		
Cos4Cloud COs: examples of information and activity demonstrating best practice:		

Engagement and participation experiences and stories are also sometimes documented as user cases to towards understanding and communicating "wider societal or policy impact". See case study example and summary of CO contributions to policy making or similar activity and lesson learned in terms of engagement and participation from some of the Cos4Cloud COs documented below.

***Pl@ntNet Impact study: evaluation**

The study was conducted to measure the impact of the initiative. We surveyed a large panel (several hundred) of Pl@ntNet users among the ones who created a user profile. We completed this survey with a usage analysis (based on google analytics tools) and several focus groups and interviews with representatives from different domains: (i) scientific field (ecology, computer science) and citizen science, (ii) agriculture, (iii) biodiversity management, (iv) education.

This impact study revealed:
Pl@ntNet is now used monthly in all countries of the world, although it is most widely used in Europe and North America. A majority of users use Pl@ntNet for their leisure time, which illustrates the important benefit of this research project for the non-academic community. This may explain the peaks in usage observed since 2013, on weekends and holidays. A majority of users used Pl@ntNet in their outdoor activities, such as in their garden, or during their hikes. This recreational activity is motivated by a variety of factors ranging from a stronger immersion in nature to gastronomy or phyto-therapy. 12% of Pl@ntNet

[95] ECSA, 2015

users use it for their professional activities (which represents a volume of more than 6,000,000 sessions mobilised for professional activities considering the total number of sessions of more than 55M). The most frequently represented professional activity is landscape management (for landscape designers, managers, architects, as well as foresters). A second important category concerns the group of people investing in the production and/or transfer of knowledge such as teachers (botany, biology, computer science), students (e.g. horticultural production), trainers (landscaping, aromatherapy, herbalism, medicine, etc.), facilitators (botanists, nature guides) and scientists (mainly biologists and computer scientists).

CO	**Examples of CO contributing to for policy-making or similar activities[96]**	**Main lessons learned by CO's in terms of engagement and participation**
Artportalen	Yes	That you need to build a system people want to use rather than focus on the data you want and expect people to deliver it to you.
iSpot	Yes. iSpot is a partner of the UK State of Nature Reporting: see 2016 report and 2019 report.	Building partnerships is important: iSpot has demonstrated substantial potential for partnerships with governmental, non-governmental and other organisations. Its online community has users from over 150 countries, posting over 800,000 observations to date, including over 1.7 million images. Engaging with specialist /groups provides expertise: There are over 200 groups, schemes and societies represented, making it a major vehicle for knowledge exchange. It is a high profile, highly valued citizen science platform. The practice of science is conducted by volunteers, either with or without direction by professional scientists. Many observations are made by amateurs, with iSpot not only helping them to generate valid scientific observations, but also effectively training them to become biological recorders.
Natusfera	No	The need to have dedicated personnel (community managers) to ensure a successful long-term engagement
Pl@ntNet	no	People are waiting for and require services. Gaining knowledge and rewards help them to remain engaged.
CanAirIO	Yes. A component of citizen science was added to the 2020 - 2024 PDD Plan de desarrollo distrital (District	The people affected by bad air quality are the more interested.

[96] CO Survey 1, June 2020

	Development Plan) Bogota, Colombia	
Fresh Water Watch	Yes	Participation is long tail! Need to adapt to the audience
OdourCollect	Working with public administrations of several countries, to build regulations. Also, in Spain, a group of experts building a norm to tackle odour pollution issues through citizen science.	First lesson: no citizens engaged, no information. So, understanding the community and being able to effectively reach them is key for OdourCollect (and all citizen science-based projects).The importance of including the quadruple helix: citizens, government, academic institutions and industries. It is key to enroll citizens and get champions, in order to ensure participation and get feedback. Strategies to engage them. Also key to set correct expectations to citizens. Online tools can be effectively used to engage citizens, public administrators and industries. Understand the community philosophy and the key NGOs within it, is a key success factor. Sensory walks are also an important activity.

5.1.10 Theme 10: COs consider "legal and ethical issues" in their design, development and management. "Ethical matters" are an important consideration in the process of collating and sharing user contributions.

ECSA Principle 10[97]::	**Principle in practice: summary challenges / examples**	**CO characteristics demonstrating best practice**
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.	Considering ethical matters is an important part of citizen science activities which involve people volunteering their time.	- How privacy is managed and data shared - Terms and conditions around copyright, intellectual property, data sharing agreements, confidentiality, attribution, etc.
Cos4Cloud COs best practice characteristics: Theme 10: COs consider legal and ethical issues as part of the technical development, management and sustainability. Intellectual property, data sharing and attribution as well as ethical matters are all important considerations. This is particularly relevant in the process of engaging participation while collating and sharing user contributions as observations supporting environmental monitoring.		

[97] ECSA, 2015

Cos4Cloud COs: examples of information and activity demonstrating best practice:

As highlighted in the Themes above, the COs in Cos4Cloud consider this in terms of the protocols / standards that COs adhere to or implement; how is privacy managed and data shared as well as user terms and conditions around copyright, intellectual property, data sharing. Facing the technological challenges of COs is a key aim of Cos4Cloud These are associated with meeting challenge of interoperability in Cos4Cloud are impacted by the technical differences i.e. programming language as well as the protocols and standards each CO adheres to. See summary of some indicators below:

CO	Programming languages of CO written in	Protocols / standards the CO adheres to or implement
Artportalen	SQL	GDPR, Darwin Core, Own classification of protected species, FAIR data
iSpot	PhP+mySQL, using Laravel and October CMS	HTTPS
Natusfera	Ruby and JavaScript	RESTful API
Pl@ntNet	Mobile front-->react Native, web front-->angular, database-->ArangoDB Search engine back-end--> C++, Rest full API	json, jpeg, (DwC) Darwin Core
CanAirIO	C++, Android, Java, Python,	GATT, JSON, CSV, websocket, https, protobuf, Cloud messages, InfluxDB line protocol
Fresh Water Watch	PHP, Javascript	In-house quality control procedures, training and automation, lab-certified data methods
iSPEX	ObjectiveC, Java (Android) MongoDB/Json	working on a SensorML interface
OdourCollect	Web/Backoffice framework: PHP Open Source, Laravel. CMS Voyager. Database mySQL. Progressive Webapp Frontend: framework javascript VUE. JSBackend: framework PHP Open Source, LaravelAPI Google MAPS	WC3 standards

5.2 General insights and lessons learned around technology and sustainability as best practice for other COs:

Sustainability was another key challenge facing COs that was considered in two contexts: maintaining technology and funding:

CO	**Main lessons learned by COs in terms of technology?** *What works or what doesn't work when creating and sustaining a CO?*	**What are the main lessons learned by CO in terms of sustainability?** *What works or what doesn't work for keeping alive the CO in the long term?*
Artportalen	Try and focus on technical scalability; scale-out. Performance problems can arise with large numbers of users loading or searching data simultaneously.	Keep delivering what the users want with constant upgrades. Do not expect users to work for you. In the case of Artportalen demonstrating to the users that data is used in environmental management encourages users to report observations. That the data is open is popular with the government agencies as the data set they use to make decisions is openly available and hence leads to more transparency in government.
iSpot	Sustained resources to maintain and update technology is important. iSpot's technology has had some redevelopment over the years but technology ages quickly and it is difficult to keep this as up to date as the team would like to.	Having a unique reputation system integrated demonstrates a system of verification of observations which is important in biological recording data. Maintaining staff support to keep up with the demands of an active online community.
Natusfera	CO should be considered as an infrastructure, with structural funding for technological support	CO should be considered as an infrastructure with long term funding programs
Pl@ntNet	Pl@ntNet and ThePlantGame tools work because people are learning something when they use them. Having some killer features in your tool makes the difference The tools must be as simple as possible to facilitate their usage.	It is easy to find fundings for developing new features or tools but not for sustaining the existing ones (even if they are really successful). A strong involvement of a few permanent staff from research organisms is necessary to ensure a minimal operation

		Donations from end-users do work above a certain number of users and allow to cover the infrastructure costs.
CanAirIO	Find developers and tech people to engage with the project.	Continuously learning about this
Fresh Water Watch	Do not try and rush the process! Subcontracting a developer can be expensive in the long run - not the most sustainable approach.	Funding is always project-based, need to check expectations when funding finishes.
iSPEX	It is hard to keep the app up to date without funding. Smartphone models change, OS changes are frequent and every device needs to be calibrated.	
OdourCollect	Having the systems that support open data (regarding odour observations) is key to gain trust from users.	Our observatory aims to clarify odour pollution issues, so we expect users to intensively participate during certain periods (3-6 months) until we can identify potential emitting sources. After these periods, the app remains available to users, in case they still want to add input to monitor the situation.

6. CO experiences in Cos4Cloud: co-designing citizen observatories services for the EOSC

Section 5, above, outlines CO best practices gleaned from the insight of the COs involved in Cos4Cloud mainly from responses to **CO Survey 1**. Building on this, Section 6 of the report, focuses on experiences about the role COs played contributing to the development, co-design and testing of Cos4Cloud's technological services. Sharing and discussing feedback on Cos4Cloud's approach addressing some of the core challenges facing COs

This is collated and summarised from the perspectives of the COs involved in the project, contributed as responses to **CO Survey 2** which focused on understanding more about the role COs have played being part the representative group of COs actively involved in Cos4Cloud, a project focused on meeting some of the operational challenges. Representatives directly involved with the development and or running of these COs contributed survey feedback.

In addition to the challenges highlighted earlier, Liu et al. (2017) identifies core developmental factors as challenges that impact on maintaining or implementing COs:

i. Technologies and data: data management to ensure quality, validity and reduce bias. This includes training tools etc to ensure participant skills for data collection.
ii. Citizen engagement: raising the interest of participants to get involved using a range of engagement activities and resources to recruit and sustain participation. This includes the benefits from being involved i.e. an informed citizenry; contributing to data; recognition, etc.
iii. Policies and framework: using COs as a source of evidence and involving citizens in bringing focus on environmental concerns
iv. Additional requirements for COs (i.e. for new COs): i.e. ensuring a functional and operational CO with the active involvement of citizens
    - Promotions i.e. tools, activities for engagement & participation
    - Creating COs that meet current and future societal needs
    - Long-lasting infrastructure - open-source, open standards
    - Addressing and evaluating citizens' views and actions on environmental matters
    - Opportunities and measures that empower citizens to influence governance processes

This highlights the important role in initiative that provides services and other outputs for COs can play to help meet challenges where "there are no systematic, easy and reusable methods" available, which "causes an insurmountable hurdle for institutions and

organisations, as they usually lack the specific technical ICT and programming knowledge to create the required server infrastructure and mobile applications. " [98] Highlighting these challenges and gathering feedback from the Cos4Cloud COs contributed to the themes of the CO surveys and CO Survey 2, in particular. The following were therefore identified as themes that emerged from the CO experiences co-designing technological services for citizen observatories.

- **Involvement of CO in Cos4Cloud:** i.e. integrating and testing services, educational activities with schools, activities with other COs, citizens scientists, other beneficiaries etc.
- **CO benefits and impact:** i.e. technical development of platform infrastructure, contributions to data, quantity / quality of observations etc., as well as benefits to and the impact on a CO user community. Also benefits and impact from the use of the CO i.e. engagement, education etc.
- **Contributions to participation in COs:** outreach and engagement initiatives to reach new or wider audiences; research etc.
- **Best practices and outcomes**: highlights from COs involvement in Cos4Cloud
- **Lessons learned:** i.e. technology (Cos4Coud Services)
- **Recommendations, legacy and benefits for other COs:** What works or doesn't work when creating or sustaining a CO.

6.1. Involvement of COs in Cos4Cloud result in the implementation of actions, initiatives and activities that contribute to the future sustainability of the platform

The Cos4Cloud COs have been involved in the project in a number of ways including integrating and testing services, educational activities with schools, activities with other COs, citizens scientists, other beneficiaries etc. Examples listed below:

Biodiversity COs:

CO Actions: Artportalen
Cos4Cloud Services- testing and integration: ● Developed an interface for Artportalen users to use the Pl@ntNet image recognition service ● Developed a module for information about verification status of observations ● Developed an API to deliver observation data to Cos4Bio **Technical infrastructure/ developments**

[98] Liu ibid.

- Built on existing infrastructure for the federation of observations to harvests observations from other Swedish data providers (i.e. Swedish iNaturalist node iNaturalist.Se.)
- Delivered a pilot project, involving collaboration between Swedish, Norwegian and Finnish mycologists. The aim was to establish permanent links between the same taxa in the taxonomic databases that are stable, even with future name changes.

CO Actions: iSpot

Cos4Cloud Services

- Pl@ntNet-API and FastCAT-Cloud integration into iSpot has included co-creation with the user community as part of the process of integrating and testing these services.
- As part of the consultation process, iForum Live sessions were facilitated with the iSpot community implemented through a new model created for synchronous live discussions at set times in the Forums. Service leads and other members of the consortium were invited to join the sessions. The community has been very active about AI on iSpot, and the discussions continue. Users have posted observations and commented on the suggestions provided by the AI.

Community engagement

- A Cos4Cloud iSpot User Group was set up to facilitate discussions and gather feedback, etc. from the iSpot Community. Supporting this process iSpot users, on their own initiatives, collated their own feedback and comments on AI Identifications using iSpot tools i.e. creating projects.
- The community and stakeholders invited to join Cos4Cloud events and use the services i.e. biological recording schemes, societies and groups in the UK i.e. NBN annual conferences etc.

Education and learning

- Activities have been developed using iSpot as an example based on the model for educational scenarios and other resources for schools developed by NKUA. These demonstration exemplars resources are part of the educational resources made available in the ***Toolbox and Evidence Hub***.

CO Actions: Natusfera

Cos4Cloud Services

Natusfera has been involved in the following activities:

- Integrating and testing the services Pl@ntNet- API and Cos4Bio
- Supporting educational activities involving schools led by Cos4Cloud partner NKUA

CO Actions: Pl@ntNet
Cos4Cloud Services Pl@ntNet has been involved in the following activities: ● Developing, integrating and testing new services (Pl@ntNet Data API, Pl@ntNet Identification API, AI-GeoSpecies, Cos4Bio, GBIF-DL, AI-Taxonomist) ● Supporting educational activities involving schools led by Cos4Cloud partner NKUA ● Supporting the integration and testing of Pl@ntNet Identification API by other COs (e.g. iSpot, Tela Botanica, ArtPortalen, Hamelin, Beekeepr, Spipoll)

CO Actions: Environmental COs / DIY devices
CanAirIO CanAirIO has been involved in Cos4Cloud the following way: ● Evaluation of DIY devices ● User engagement ● DIY guides, best practices ● Supporting an open-source community
iSPEX ● Integrating the iSPEX spectrometer in the MOBIS app and framework ● No iSPEX campaigns yet, the focus has been on providing an interface for iSPEX captures.
FreshWater Watch ● Hoping to integrate Cos4Env in the near future
Kduino ● Demonstrating the integration of DIY technologies
OdourCollect ● Integrating and testing services: MECODA, Cos4Env, Supporting educational activities in Greece with Cos4Cloud partner NKUA and leading activities in Barcelona i.e. a testing event with MECODA using OdourCollect data in a school in Barcelona ● Several field campaigns (in collaboration with other projects such as H2020 MONOCLE). Some international collaboration in Brazil.

6.2 COs benefit from involvement in Cos4Cloud: impact on CO infrastructure

Examples of benefits and impact suggested by the COs in Cos4Cloud focused on technical development of platform infrastructure, contributions to data, quantity / quality of observations etc. :

Biodiversity COs Benefits and Impact

• More efficient quality control through an enhanced possibility for verification of observations and making the information publicly available and traceable.
• Gained a lot of experience with image recognition - both its advantages and its limitations. For **Artportalen** impact so far? "not much, but the image recognition service is relatively new and we are still waiting for a specification on how to receive verifications back from the Expert Portal."[99] Artportalen has close to 100 million observations that could be found through Cos4Bio.
• Evaluating impact will need time, some COs have large, active communities which could make it difficult to do.
• Possibilities for data validation from the Integration with other biodiversity platforms through Cos4Bio i.e. **Natusfera**
• Having a technical team in place to adapt platforms and integrate A I. This support also contributed to the stability of the infrastructure i.e**. iSpot**.
• As a CO directly involved in the development of services i.e**. Pl@ntNet** and the Pl@ntNetAPI:
  • data quality and accessibility enhancement
  • better interoperability with other portals, applications and platforms (e.g. GBIF, INPN, other COs, hundreds of web and mobile applications, etc.)
  • better recognition of the contributors' work
  • increased scientific impact (more citations of the shared data, more researchers using the API, etc.)

Environmental COs / DIY devices: Benefits and Impact
• Improvement of technical infrastructure, example the iPhone app developed by MOBIS i.e. **CanAirIO** • Better DIY guides and data quality • Compatibility with biodiversity standards like Darwin Core i.e. interoperability • New data analysis opportunities through integration with MECODA i.e. **CanAirIO** and **OdourCollect**

[99] CO Survey 2, December 2022

- Better platform technology, with data more easily accessible.
- Interoperability with systems like the Darwin core API brings new opportunities
- Enabled continued development i.e. a (data) platform for **iSPEX**
- Possible benefits anticipated from future integration i.e. through Cos4Env **FreshWater Watch** will encourage the use of its data among experts in environmental monitoring.
- Possibilities for data validation from the Integration with other air quality platforms through Cos4Env i.e**. OdourCollect**

CO Survey 2 also asked the COs to note what they considered as the main outcomes from being involved in Cos4Cloud and what these experiences fulfilled for the CO. The following list of common characteristics was collated:

- More collaboration with experts and others in other countries
- The adoption of new technology
- The importance of having mechanisms in place for continuity i.e. maintaining a project team

Artportalen is a relatively mature system, but has seen the positive impact on the CO's growth and development

- Enhanced technology infrastructure including the integration of new services which the CO would otherwise not have been able to implement as well as helped to standardise existing operations i.e. **OdourCollect** API.

iSpot also saw additional benefits such as enhanced engagement with the user community with the technical team and these discussions saw collaboration in the development of new ideas, or enhanced old ones, iSpot developers could respond and speak directly to the community which gave both community and developers confidence. In addition to the integration of services key results included updates to the species dictionaries to align better with observations and data with other COs/services. There was collaboration and co-creation as the community identified areas they could help directly on and initiated actions working with the team.

- The development of quality and implementation of services following FAIR principles and making them open and accessible, contributed to interoperability as well as greatly enhancing the societal impact of COs involved in service development.
- Strengthening of the CO with the development if and advancement of the way the CO is used

6.3 Cos4Cloud contributes to COs through the implementation of outreach, engagement and communications initiatives and actions and other methods contributing to user participation

For the COs involvement in Cos4Cloud had an impact on the COs outreach and engagement and participation. **CO Survey 2** also asked COs to note what they considered as the main outcomes from being involved in Cos4Cloud and what these experiences fulfilled for the CO. the following common characteristics and examples were collated:

Cos4Cloud facilitated the development of experience and expertise with school-based audience and involvement of the CO in educational scenarios:

As a CO that was involved in Cos4Cloud citizen science and environmental education school-based initiatives, **OdourCollect** has benefitted from:

- More than 200 new observations in Greece due to the use of OdourCollect in schools
- Exploring new synergies of the observatory with air pollution, education and data sciences. Other activities are being planned and it is anticipated these will further improve the types of activities that can be delivered with the service..
- Integration of OdourCollect through MECODA contributed to wider use of the CO platform for educational purposes. This also contributed to the increased use and analysis of OdourCollect.[100]

Cos4Cloud facilitated experiences contributing the development and access to new outreach resources:

iSpot's involvement in Cos4Cloud enhanced and increased some areas of engagement and outreach. For example, a monthly newsletter / blog was developed to provide regular feedback and information to reach the community and showcase Cos4Cloud events and encourage community engagement. Outreach including introducing Cos4Cloud services to new audiences at events both online and face to face; examples include the Milton Keynes Parks Trust Love Nature Day event, Citizen Science Month activities, ECSA Conferences, and NBN Conferences. As a co-host of the latter engagement included a iSpot bioblitz for Cos4Cloud.

Cos4Cloud presents positive benefits and impact on CO user community in different ways:

iSpot community user case study - impact of AI integration
As one of the Cos4Cloud biodiversity COs involved, iSpot has advanced its technology with AI and machine learning integration i.e. the Pl@ntNet API and FASTCAT-Cloud and has benefitted from this experience both technically and through user engagement.

[100] OdourCollect, CO Survey 2, December 2022

Discussion about AI, its potential and impact has grown and has stimulated a lot more users to become involved. Some users have developed an interest in investigating species using AI within iSpot. The iSpot community has become much more familiar with AI and reviewing why AI integration works/benefits/detracts.

In addition to this, the impact of Cos4Cloud on the CO user community, though the integration of services contributed to the initiation of innovative engagement and outreach activities. The community provided very direct feedback – discussions and debates have been enhanced along with observations from the community to showcase how human interaction is crucial for the learning element within the observation itself. Indeed sometimes to the detriment of AI due to some resistance at AIs ability to enhance or improve observations.

Indirectly, this has enhanced iSpot community contributions to show how human interaction is crucial to providing improved observations to enhance learning and provide more accurate identifications. Direct impact / contribution to iSpot data not yet noticeable but some users, from the testing feedback provided, have highlighted examples where the AI has helped with identifications. The community is also using the systems and now more familiar with AI and more willing to review and critique it, providing very useful feedback.

Cos4Cloud also contributed to:

- Engagement with and expansion to more audiences
- COs integrating the services also benefitted from the publicity and being promoted as the first exemplars demonstrating the use and integration of codesigned services with user cases i.e. case studies developed for wider use
- New possibilities for research and scientific papers highlighting Cos4Cloud experiences

Pl@ntNet's involvement has had a positive impact in fields as varied as: research, education, conservation, agro-ecology, horticulture or even tourism or health.

6.4 CO participation in Cos4Cloud delivers outcomes and lesson learned which can be collated and presented as best practice for other COs

CO Survey 2 also asked the COs to note what they considered as best practice and outcomes highlights from COs involvement in Cos4Cloud as well as lessons learned: i.e. technology (Cos4Coud Services)from being involved in the following examples were collated:

Examples of CO best practice from the experience of being involved in Cos4Cloud that may help other COs
• Set aside resources (time and money) in order to establish contact with other countries, perhaps mainly with neighbouring ones, since they are more likely to share fauna and flora as well as having shared borders which invasive alien species have to cross • Keep in touch with others doing similar work so that you don't develop things that someone else has already done • Don't rely on a single person to keep something important working • Getting the technical team and developers involved with the community so that day to day items could quickly be resolved and co-creation happened. Often items the community wanted were too much but because they were trusted by the community everyone understood what could or could not happen. • It is important that the work of the observatory's contributors be valued in the form of quality services and tools that can benefit the greatest number of actors. Going beyond the dissemination of data and scientific knowledge in a crude manner is crucial to make the observatory successful. The cooperative learning of AI algorithms, in particular, is a fantastic way to pool the community's knowledge in a single tool shared by all. • Open your platform to different standards, such as biodiversity, open up new audiences and opportunities. • Webinars and international participation are key to creating new audiences. • Our experience may help to better technology integration. • MECODA use for high schools has a great potential and it is something we will continue offering.

6.5 Cos4Cloud as an outreach methodology: Legacy, outcomes and recommendations for other COs

CO Survey 2 also asked the COs to share experiences, lesson learned and recommendations that could be useful for other COs. i.e. What are the main lessons learned (including any integration and testing of Cos4CLoud Services)? What works or what doesn't work when creating or sustaining a CO.?

The following examples were collated from some of the COs involved:

CO	CO Cos4Cloud experiences that should be highlighted	Examples from COs involvement in Cos4Cloud that could be beneficial to other citizen observatories	Lessons learned from Cos4Cloud: What works or what doesn't work when creating or sustaining a CO?
Artportalen	An obvious benefit is having resources for developing useful services.	We managed to integrate Cos4Cloud services into our existing system, or even just modifying existing parts to comply with Cos4Cloud standards.	Securing long term funding is important to keep the users engaged by giving them what they want rather than trying to force them to give you what you want. And, finally, they get a service for free while we get their observations for free = win win.
iSpot	Being part of the project has resulted in additional interaction from the iSpot community. With this experience we are thinking of other opportunities for future research.	Collaborating and sharing with other COs: The Cos4Cloud project has enhanced iSpot's relationship between and with other COs and service leads	One important lesson is that irrespective of whether something technically 'works', the existing community of users' needs to be onboard as this helps improve it. For example, the community spotted differences in how the Pl@ntNet API was working in iSpot and provided feedback which helped to improve the functionality as it was implemented.
Pl@ntNet	The fact that we have to share Pl@ntNet data and algorithms in the form of open services developed in the framework of Cos4Cloud has led us to greatly improve the platform in terms of data quality, robustness of services, interoperability, accessibility and reusability.	Pl@ntNet API now has more than 6000 developer accounts for This shows how the development of FAIR and quality services can extend the impact of an observatory well beyond its own community of contributors / users. Pl@ntNet is a pioneer observatory in the development of AI algorithms for citizen science and has made this accessible to a large community of actors i.e. other COs, companies, research organizations, etc	New technologies work only if they answer to a real user needs or if the user or if the users clearly understand the direct impact on society/biodiversity. "Nice-to-have" technologies may work for a while but only "Need-to-have" technologies are successful in the long term.

CO	CO Cos4Cloud experiences that should be highlighted	Examples from COs involvement in Cos4Cloud that could be beneficial to other citizen observatories	Lessons learned from Cos4Cloud: What works or what doesn't work when creating or sustaining a CO?
CanAirIO	Biodiversity standards are useful in environmental COs such CanAirIO and AireCiudadano[101].	DIY COs can benefit from services like MECODA and Cos4ENnv to make data more widely available and facilitate data analysis	Is very important to have compatible APIs with other domains like the biodiversity (i.e. Darwin Core protocol)
iSPEX	The framework developed for MOBIS has been a useful starting point for the developments to iSPEX .	By providing an interface service may contribute to making a CO sustainable.	For any CO to work, especially iSPEX, which is very technical by nature, there has to be a very nice user interface that provides almost instant feedback.
FreshWater Watch	Learned a lot from other DIY instruments, which could guide a lot for future engagement activities.	Our experience may help in better technology integration i.e. widening the citizen science capabilities to different applications (i.e. water quality monitoring).	The main bottle neck has been the delays on the new implementation
OdourCollect	We helped in the development of Cos4Env, integrating our data there. Also with MECODA we worked closely to develop several plugins for data analysis.	The use of MECODA was beneficial. It is a service that can be very useful for OdourCollect.	Improvements in interoperability and accessibility, new opportunities to incorporate new functionalities and explore new paradigms

[101] Aire Cuidano: https://aireciudadano.com/

CO Survey 2 also asked COs to share what they considered as the legacy of Cos4Cloud from their experience i.e. a new technological service, tools and experience to engage new audiences etc. and The following examples were collated:

Legacy of Cos4Cloud for COs

• Image Recognition services that are free for any CO to use.
• Validation services. For example:
  ○ **Artportalen** has benefited with a large contribution to the enhancing the COs Verification Module which does much more by receiving verifications from Cos4Bio and displaying them publicly.
• Benefits from the experience of being involved with a EOSC project.
• The addition of AI and improvements which have helped to improve stability of a CO platform and being part of a co-design process has also helped to improve some aspects of communications with CO users. For example:
  ○ **iSpot** has seen more direct engagement between programmers and the user community .
• The new services provide new features that benefit CO user communities which helps to improve the quality of data after their experience using them.
  ○ On **iSpot** there is evidence that members of the community are improving the quality of observations after their experience with AI IDs. Some users are adding more information to make 'better' observations i.e. including more of the key features of the organisms.
• Development of environmental education with schools involved some services and COS has provided a legacy for future activities to further contribute to and enhancing citizen science and learning possibilities
• A key legacy of Cos4Cloud for some services will be the public APIs developed. For example:
  ○ For **Pl@ntNet** use of the API has opened the platform to the world of developers and, thanks to this, has enhanced connections to many other CO platforms and applications in a sustainable way.
• MECODA has provided possibilities for CO data analysis i.e. **OdourCollect**, **CanAirIO**
• The Cos4Env service has made CO data more widely accessible and is building connections between different CO sources and types of environmental data.
• Co-designing services has resulted in the development of better DIY guides for devices.
• Involvement with Cos4Cloud communication and engagement has contributed to better public engagement strategies for some COs i.e. **CanAirIO**.

- Development of new technological services, tools and experience to engage new audiences - particularly experts in environmental modelling - and an opportunity to contribute to further research i.e. **FreshWater Watch**
- COs have the use of services developed with a solid foundation connecting them to a unified, open and FAIR infrastructure. For example
    - iSpex provides a toolbox that can be customised to create apps and web services.
- Better and stronger collaboration between different citizen science initiatives i.e. **KdUino**, **Natusfera**
- Benefits from the collective body of knowledge generated from Cos4Cloud which presents future possibilities for collaborations i.e. integrating other services etc. i.e. **OdourCollect, iSpot**

7. Creating Guidelines and best practice resources

The results from both surveys contributed to ***D6.2 Guidelines on Best Practice for COs as part of the Outreach Methodology Report*** as well as the development of best practice guidelines which are being made available as part of ***D6.3 The Cos4Cloud Toolbox and Evidence Hub.*** In this context, best practice was defined as a set of guidelines i.e. how to carry out a task, that if followed can result in good outcomes. This focused on citizen observatories through the experiences of COs directly involved in the project and included practical examples highlighting Cos4Cloud's impact on the technological capabilities of citizen observatories based on CO experiences. Both surveys also presented information on the engagement of participants, public participation in scientific research, while facilitating knowledge sharing, learning and building skills, etc. This is viewed as an important part of the growth of COs, playing a significant role in biodiversity recording and environmental monitoring[102].

7.1 CO best practice – Guidelines for other citizen observatories

Section 5 above, used the ECSA's Ten Principles of Citizen Science to present relevant themes from Cos4Cloud CO Survey feedback. It has been applied as a framework for CO best practice given its role, "serving as a principled guide for all citizen science project developers and practitioners"[103]. This is supported by recommendations that close connections should be made to the ECSA Ten Principles as this supports planning, design, management and the implementation of best practice. The themes that emerged from

[102] We Observe, 2018.
[103] Sturm U, et al, 2017

the analysis of CO Survey contributions has been used to shape the following as ***Guidelines on best practice for citizen observatories[104]:***

Guideline 1: COs "use digital technologies"[105] to "actively involve citizens in scientific endeavour[s] that generate new knowledge or understanding"[106]

Cos4Cloud COs best practice characteristics: COs use digital technologies to actively involve citizens. A clearly outlined purpose / objective, framed by the environmental or scientific topic, defines the type of observations that are contributed, and the type of data collected. The defined geographic focus and languages available contribute to how this can be communicated to engage participants. Evidence of involvement can be tracked over time through user participation and this activity demonstrates examples that "actively involve citizens" and the role they play "in scientific endeavour[s] that generate new knowledge or understanding".

Guideline 2: COs contribute to research that can achieve a "science outcome"[107], supporting "learning and research"[108] while facilitating participation, engagement and outreach

Cos4Cloud COs best practice characteristics: Users contribute observations to COs through established protocols based on the scientific discipline / field. This provides data which is made available as a source for research i.e. scientific publications etc., that can achieve a science outcome. This also supports education and learning while facilitating participation, engagement and outreach.

Guideline 3: COs involve a range of groups who "benefit from taking part"[109] in different ways i.e. "scientific outcomes, social interaction, skills development, learning etc "[110]

Cos4Cloud COs best practice characteristics: COs involve professional scientists, experts citizen scientists and a range of other different groups and all can "benefit from taking part" in different ways i.e. research outputs, contributing to scientific evidence, learning opportunities, skills development, personal enjoyment, etc. A range of educational, engagement and outreach tools and resources are also developed and disseminated which support participation.

[104] Key terms highlighted in quotations are quoted from the ECSA Ten Principles, ECSA 2015 and / or Robinson et al, 2018. See framework in Table 1 for further information.
[105] Robinson et al, 2018
[106] ECSA, 2015, Principle 1
[107] ECSA, 2015, Principle 2
[108] Robinson et al, 2018
[109] ECSA 2015, Principle 3
[110] Robinson, 2018

Guideline 4: COs provide a platform where users can "participate in multiple stages"[111] of research

Cos4Cloud COs best practice characteristics: Participation in citizen science initiatives is defined by different typologies that can involve multiple stages. COs also facilitate engagement in different ways including crowdsourcing, validating or confirming identification of observations; as well as through social interaction which also facilitate a process of feedback This supports collaboration i.e. through collaborative and personalised approaches and co-creation through the use of integrated tools or creating DIY devices . Lessons learned demonstrate impact in terms of participation in different levels and multiple stages of the scientific process.

Guideline 5: COs involve users and provide "feedback"[112] as part of the process of engagement and participation

Cos4Cloud COs best practice characteristics: CO user involvement is supported and encouraged through both giving and receiving feedback to and from users, as a two-way process of engagement. Options for users to provide this is an important part of the participatory process also. For example many COs, particularly those focused on biodiversity, feedback as validation agreement etc is part of the crowdsourcing of identifications within the community as part of the ID process. However, more structured public feedback is integrated as part of engagement and outreach i.e. news, social media etc.

Guideline 6: COs are an important part of the citizen science scene. They make contributions as "research" infrastructures therefore similar control of "limitations and biases"[113] apply

Cos4Cloud COs best practice characteristics: COs are an important part of the development and growth of citizen science. They make contributions as research infrastructures therefore similar control of "limitations and biases" apply. Data management is a core consideration to ensure that relevant guidance and measures are implemented to reduce possibilities for errors and bias as well as increase the validity and accuracy of citizen science data.

Guideline 7: COs promote "open data" and "metadata" practices while ensuring that data is accessible and "publicly available"[114].

Cos4Cloud COs best practice characteristics: COs promote open data and work together on metadata practices while ensuring that data is accessible and publicly

[111] ECSA 2015, Principle 4
[112] ECSA 2015, Principle 5
[113] ECSA 2015, Principle 6
[114] ECSA 2015, Principle 7

available. CO data is made available using web-based applications and technology. How COs manage data as well as the licences used for sharing are also key.

Guideline 8: COs have built in "recognition"[115] systems which acknowledges[116] user contributions and communicates results from the user community

Cos4Cloud COs best practice characteristics: Theme 8: COs have built in recognition systems i.e. user badges, which acknowledge and recognise their contributions. User observations and other metrics are recorded, monitored and tracked using different tools. Information and results are communicated acknowledging the user community in publications etc.

Guideline 9: CO's conduct "evaluation"[117] in different ways: studies on impact, use of data as a "scientific output", etc; experiences and stories are also sometimes documented towards understanding "wider societal [or] policy impact"[118]

Cos4Cloud COs best practice characteristics: Although not always possible to do, CO's conduct "evaluation" documenting outcomes in different ways: studies on impact, use of data, etc. Engagement and participation experiences and user stories are also sometimes documented as user cases. Through their actions COs demonstrate interest in collecting and sharing stories as a contribution to evaluating impact as well as towards understanding and communicating "wider societal or policy impact".

Guideline 10: COs consider "legal and ethical issues"[119] in their design, development and management. "Ethical matters"[120] are an important consideration in the process of collating and sharing user contributions.

Cos4Cloud COs best practice characteristics: COs consider legal and ethical issues as part of the technical development, management and sustainability. Intellectual property, data sharing and attribution as well as ethical matters are all important considerations. This is particularly relevant in the process of engaging participation while collating and sharing user contributions as observations supporting environmental monitoring.

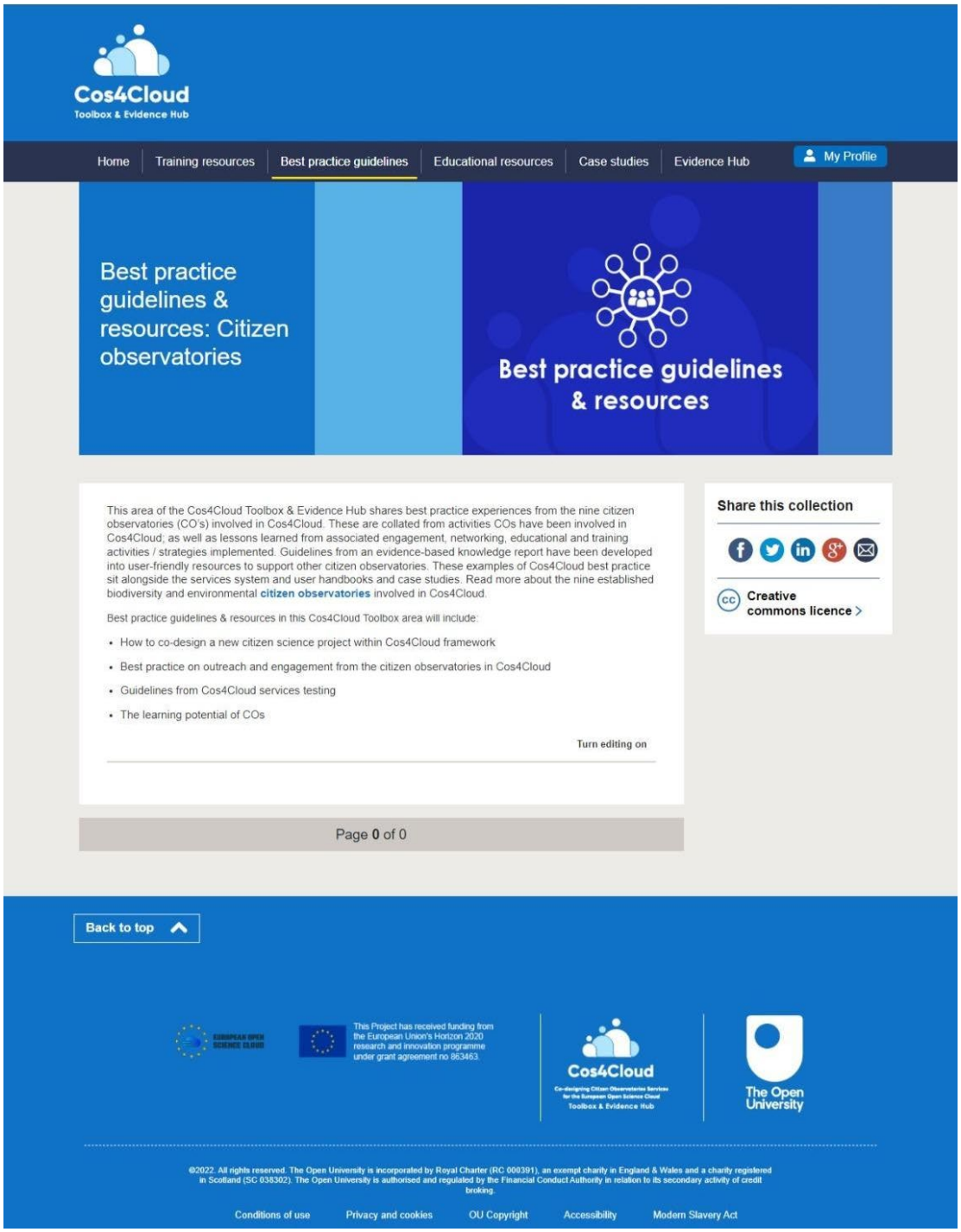
7.2 Best practice guidelines and other resources

In summary, the range of examples from presented from the CO Surveys provided by COs involved in Cos4Cloud presented in Section 5 outlines experiences and .insight demonstrating these as guidelines that can be of relevance to other COs. The

[115] Robinson et al, 2018
[116] ECSA 2015, Principle 8
[117] Robinson et al, 2018
[118] ECSA 2015, Principle 9
[119] ECSA 2015, Principle 10
[120] Robinson et al, 2018

development of these guidelines is further implemented as part of the **Cos4Cloud Toolbox and Evidence Hub** (OLCreate: Cos4Cloud Toolbox and Evidence Hub (open.edu) and made available as **Best Practice Guidelines and Resources** here: OLCreate: Best practice guidelines & resources: Citizen observatories (open.edu).

Figure 8 Best Practice Guidelines and Resources in the Cos4Cloud Toolbox and Evidence Hub



Best practice guidelines - development framework

This area of the Cos4Cloud Toolbox & Evidence Hub shares best practice experiences from the nine citizen observatories (CO's) involved in Cos4Cloud, as well as other examples of CO involvement. These are collated from activities COs have been involved in Cos4Cloud; as well as lessons learned from associated engagement, networking, educational and training activities / strategies implemented.

Guidelines from this evidence-based knowledge report are being developed into user-friendly resources to support other citizen observatories. These examples of Cos4Cloud best practice sit alongside the services system, administrator and user handbooks, guides and case studies. The Toolbox and Evidence Hub is being showcased as a recognisable collection of Cos4Cloud project outputs and promoted as a legacy of the Cos4Cloud project.

8. Next steps for COs as part of Cos4Cloud's outreach methodology

In addition to modelling a framework for the development of guidelines of best practice, framed by themes from the ECSA Ten Principles, this report focused on identifying experiences from the COs associated with Cos4Cloud, demonstrating characteristics from the project delivery. This shapes ***Cos4Cloud as an outreach methodology*** a body of knowledge demonstrated and shared though the services , supporting resources and other outputs etc that can be used by other COs to help meet the challenges they face.

Cos4cloud identifies the following core characteristics and the services developed by the project focused on addressing these as major challenges facing COs[121]

- Efficient capture, identification and validation of data.
  Interaction between participants using approached that facilitate "the transfer of knowledge and, the stewardship and storage of large volumes of data in different formats (photos, sounds, camera trap images etc.)".
- Interoperability at a local, regional and global level
  Scaling the collection, access and use of (i.e. potential impact) of CO data across geographic, thematic, language etc. barriers for research and other purposes.
- Long-term sustainability challenges w
  Difficulties accessing and obtaining resources to develop and implement current and viable technological functionality .

[121] Piera, 2020

Cos4Cloud responds to these as identified needs to provide innovative services supporting integration in the EOSC widen the scope for and use of COs and citizen science.

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8.1. Cos4Cloud CO characteristics contributing to Cos4Cloud Outreach methodology

Cos4Cloud as an outreach methodology highlights the important role played by an initiative that provides services and other outputs for COs to help meet challenges where "there are no systematic, easy and reusable methods" available, which "causes an insurmountable hurdle for institutions and organisations, as they usually lack the specific technical ICT and programming knowledge to create the required server infrastructure and mobile applications. " [122] Highlighting these challenges and gathering feedback from the Cos4Cloud COs contributed to the themes of the CO surveys, and CO Survey 2, in particular. The following were therefore identified as themes that emerged from the CO experiences co-designing technological services for citizen observatories.

Involvement of CO in Cos4Cloud: i.e. integrating and testing services, educational activities with schools, activities with other COs, citizens scientists, other beneficiaries etc.

- Involvement of COs in Cos4Cloud result in the implementation of actions , initiatives and activities that contribute to the future sustainability of the platform
- The Cos4Cloud COs have been involved in a number of ways including integrating and testing services, educational activities with schools, activities with other COs, citizens scientists, other beneficiaries etc.

CO benefits and impact: i.e. technical development of platform infrastructure, contributions to data, quantity / quality of observations etc., as well as benefits to and the impact on a CO user community. Also benefits and impact from the use of the CO i.e. engagement, education etc.

- COs benefit from involvement in Cos4Cloud with results having an impact on CO engagement and participation
- Examples of Cos4Cloud CO benefits and impact include. technical development of platform infrastructure, contributions to data, quantity / quality of observations etc,;
- impact on the CO user community, in the use of the CO, etc.

Contributions to participation in COs: outreach and engagement initiatives to reach

[122] Liu ibid.

new or wider audiences; research etc.

- Cos4Cloud contributes to COs through the implementation of outreach, engagement and communications initiatives and actions and other methods contributing to user participation
- Contributions to participation in COs: outreach and engagement initiatives to reach new or wider audiences; research etc.

Best practices and outcomes: highlights from COs involvement in Cos4Cloud

- CO participation in Cos4Cloud delivers, outcomes and lesson learned which can be collated and presented as best practices for other COs

Lessons learned: i.e. technology (Cos4Coud Services) and **Recommendations, legacy and benefits for other COs:** What works or doesn't work when creating or sustaining a CO.

- Outputs and legacy documenting recommendations for other COs: What works or doesn't work when creating or sustaining a CO
-
- Recommendations for other COs: What works or doesn't work when creating or sustaining a CO

8.2. Conclusion

As noted earlier, COs share similarities which ,when presented as a model, help to identify the main requirements and role "as a method for data collection"[123] . This includes the ability to engage and participate in data collection etc.; interaction with citizens and other stakeholders; as well as the use of technology. Altogether this CO framework and approached identifying a Cos4Cloud Outreach Methodology supports effective citizen participation;[124] elements which were discussed in the CO examples identified throughout this report.

The insight from these experiences has been shared in this report as part of Cos4Cloud knowledge transfer to help support and develop CO's and other initiatives interested in using Cos4cloud approaches as an outreach methodology. This knowledge base also includes insight from information contributed as part of sharing between the COS and other partners within the Cos4Cloud consortium (i.e. actions, activities, discussions, workshops etc.). This further contributes to the creation of guidelines and resources on how to *co-design a citizen observatory or citizen science project within the Cos4Cloud framework* which will be shared as part of **the Cos4Cloud Toolbox & Evidence Hub**.

[123] Liu, H-Y, et al, 2017
[124] ibid

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Appendix 1: CO Survey 1, June 2020

COS4CLOUD CITIZEN OBSERVATORIES' SURVEY 1 (JUNE 2020)

Cos4Cloud seeks to boost the technological capabilities of citizen observatories. In order to do so, it is important for us to better understand the shared needs and differences among the nine citizen observatories within our consortium.

This survey was created by the CoNNect group. CoNNect comprise the team within work packages 5, 6, 7 and 8 and it works in topics as communication, engagement, co-design, networking, governance, training and testing of the Cos4Cloud services.

The information collected in this survey will be used for the Cos4Cloud's [second/2nd] general meeting as well as research purposes of the project.

Please review the PDF file with the questions, and once you're ready, fill the form. The deadline for responding to the survey is **4th June 2020.**

For questions of comments related to this survey write to Karen Soacha soacha@icm.csic.es. Thank you for

time and contributions.

No.	Question	Type	Options
	Introductory section		
	Name and email of the person filling out the survey	Open	
	Organization	Open	
	Role of the person within the citizen observatory	Open	
	General section		
1	Name of the citizen observatory (CO onwards)	Open	

2	CO's acronym	Open	
3	Years the CO has been running (timeline)	Open	
4	What is the main objective the CO seeks to fulfil?	Open	Open
5	What disciplinary fields/topics is the CO active in?	Multiple choice	- Biodiversity - Air quality - Water quality - Others (explain what)
6	Is the CO currently functional? If not, why not and what is the estimated date for having an operational version?	Open	
	Data collection		
7	What data does the CO collect?	Multiple choice	- Biological records - PM 2.5 values - Coordinates - Photos - Sounds - Other (explain what)
8 (a)	Geographical focus of the CO	Multiple choice	- Local - National - European - International -
8 (b)	Observations from which countries are most prevalent in your CO?	Open	
9	What languages does the CO support?	Multiple choice	- List of languages

10	Is it possible to add a new language, for instance, Greek?	Open	
	Technical information		
11	Which programming languages is the CO written in (i.e. Front end and back end, database, etc.)?	Open	
12	What protocols/standards does the CO adhere to or implement?	Open	
13	Does the CO have a data management plan?	Open	
14	Where is the CO storing the data collected?	Open	
15	What licences are used for sharing data?	Open	
	Engagement		
16	How would you describe the main groups that use the CO? Use: contributing to data, using for educational activities, creating research, among others.	Open	- Educational sector (i.e. schools, teachers) - Academy research - NGO - Government - Industries - Amateurs - Students - Researchers - Farmers - Activists - Urban citizens - Others (explain who)
17	How many users does the CO have?	Open	

18	a) Does the CO collect testimonials of the most active members? b) If yes, are they publicly available? c) If not, would you be interested in collecting testimonials with the support of our communication team?	Yes/no Yes/no Open	
19	a) Has the CO documented success stories? i.e. EOSC Amnesia service https://www.eosc-hub.eu/collaborations/openaire-advance/published-private b) If yes, are they publicly available? c) If not, are you interested in working with our communication team to develop such documentation?	Yes/no Open	
20	(a) Have you ever used co-design strategies within your CO? (b) If yes, please, indicate how you have organized a co-design session, for what purpose, where, how you have engaged your participants, which methods for co-design you have used, etc.	Yes/no Open	
21	Does the CO have a calendar of activities or online strategies for the next months or years? If yes, would you be able to share that with us?	Open	
	Training and educational tools and resources		
22	What resources (i.e. set of guidelines, tutorials, promo/ info videos, leaflets, training courses/ webinars, etc) have you developed (add links if available), are developing, or could develop to train various target groups (i.e. NGO activists, teachers, etc) on using your CO?	Open	

23	Has the CO created tools (i.e. embedded quizzes etc) and / or developed any educational/learning activities with schools, universities, or any forms of informal learning and training? If yes, please specify what was created, when (including whether it is still actively used) and briefly describe the tools, courses or activities (add links if available)?	Open	
	Performance		
24	What kind of metrics do you use for measuring the COs performance/activities/impact (i.e Number of participants, citations)?	Open	
25	What do you use to collect these metrics (i.e. Google analytics)?	Open	
	Use an Impact		
26	How have people used your CO? Describe the different use cases (i.e. bioblitz, monitoring phenology, monitoring fauna, IUCN Red list assessment)	Open	
27	a) Has your CO been used as a source of data or as a resource for a scientific publication? b) If yes, how was it or members of the team cited or otherwise acknowledged in the publication? c) Do you have a collection / list of such publications (add links if available)?	Yes/No Open	
28	Has your CO been used for educational purposes, i.e. within a school, curricular or extracurricular, context?		

29	Have insights generated by your CO been used for policy-making or similar activities?	Open	
	Governance structure		
30	What is the CO's governance structure?	Open	
31	Who makes the decisions about the management of the citizen observatory data (Infrastructure, storage of data, licences, access)?	Open	
32	Who decides about technical and sustainability aspects of the CO?	Open	
33	How does the CO manage the recognition and acknowledgement of the contributors?	Open	
	Lessons learned		
34	What are the main lessons learned by your CO in terms of engagement (i.e. citizen scientists, scientists, other users)?	Open	
35	What are the main lessons learned by your CO from experiences developing materials like tutorials, guidelines or similar for facilitating the use of the CO?	Open	
36	What are the main lessons learned by your CO in terms of technology? What works or what doesn't work when you are creating and sustaining a CO?	Open	
37	What are the main lessons learned by your CO in terms of ensuring reliability? What works or what doesn't work for creating trustworthy data and information?	Open	
38	What are the main lessons learned by your CO in terms of sustainability? What works or what doesn't work for keeping alive the CO in the long term?	Open	

	Sustainability		
39	How many people are involved in the operation of the CO? What are their roles?	Open	
40	What are the main sources of funding for the CO?	Multiple choice	% -Public -Private -Crowdfunding - Other
41	What are the main costs for your CO (i.e. personal, infrastructure, development of software)?	Open	

Appendix 2: CO Survey 2, December 2022

Citizen Observatories (CO) survey 2: Cos4Cloud best practice for other COs (December 2022)

As you are aware, **Cos4Cloud** (https://cos4cloud-eosc.eu/) includes the participation of **9 established citizen observatories (COs) and Do it Yourself (DIY) initiatives** (Artportalen, CanAirIO, FreshWater Watch, Kduino, iSPEX, iSpotnature, OdourCollect, Pl@ntNet, Natusfera). These COs have supported the development of the

Cos4Cloud **technological services** by integrating and testing these services as well as providing a wide range of expertise which has contributed to the delivery of Cos4Cloud.

Cos4Cloud Citizen Observatory (CO) Surveys:

The first CO survey, conducted in 2020, focused on collating information helping us understand the shared needs and differences amongst the COs involved in Cos4Cloud and this information has already contributed to associated reports and deliverables particularly associated with WPs 5, 6 and 8.

This second and final Cos4Cloud CO survey, seeks to gather perspectives, suggestions and comments from the CO leaders about the experiences of the COs associated with Cos4Cloud that can help other COs make the best use of the project's outputs. This includes how a CO can be enhanced and developed within a Cos4Cloud framework and demonstrations of best practice for citizen observatories from the 9 COs involved.
In this context best practice can be defined as a set of guidelines i.e. how to carry out a task, that if followed can result in good outcomes.

Feedback from those involved with running these COs is an important contribution to finalising reports guidelines and resources for COs showcasing how Cos4Cloud can boost the technological capabilities of citizen observatories while increasing and improving the quantity and quality of observations. Information from both surveys contributes directly to the following WP6 project deliverables:

- **D6.2 A Report on guidelines on best practice for COs as part of Cos4Cloud's outreach methodology**
- **M6.3 Best practice guidelines and resources for building citizen observatories**
- **D6.3 the Cos4Cloud Toolbox and Evidence Hub, currently under development, which will host and share the resources developed.**

Please submit your responses by Thursday December 22, 2022.

We do appreciate we are very close to Christmas break but really hope you can spare the time to provide this important information. Thank you for your assistance! Any comments or queries contact: janice.ansine@open.ac.uk

* Required

CO Survey 2: Experiences from the COs in Cos4Cloud

Please answer the following questions to help us gather a better understanding of your CO's role and contributions in Cos4Cloud

1. Name of person filling out the survey *

2. Partner Organisation *

3. Name of the citizen observatory or DIY initiative involved (all called COs onwards) *

- [ ] Artportalen
- [ ] CanAirIO
- [ ] FreshWater Watch
- [ ] Kduino
- [ ] iSPEX
- [ ] iSpotnature
- [ ] OdourCollect
- [ ] Pl@ntNet
- [ ] Natusfera

4. Role of the person with the CO *

5. What has been the involvement of this CO in Cos4Cloud? What aspects of delivery has the expertise of your CO directly or indirectly contributed to?

Please describe your example(s) and provide as much information as possible about the involvement of the named CO in these activities. *

You can include as many examples as possible, for each one please state: what was the COs involvement? what did the CO contribute to? Examples of CO involvement can include: i). integrating and testing services, ii) supporting an educational activity involving schools i.e. with NKUA or others, iii) any activity involving other COs, citizens scientists or other beneficiaries iv) any other.

6. How has the CO benefitted from this experience? *

   This can include: i). technical benefits i.e. development of platform infrastructure ; ii). contributing to data iii) quantity / quality of observations (please specify) iv) any other.

7. When did these experience(s) / activity (ies) take place? Who were the main participants?

8. What has been the impact on the CO user community? How has this contributed to the use of the CO? *

9. How has this involvement contributed to the COs outreach? This can include publicity and or public engagement i.e. reaching new or wider audiences, research etc. *

10. Based on the activities described above, what would you say is the main outcome of your COs involvement in Cos4Cloud ? What did these experiences fulfil for the CO? *

11. How would you describe these as examples of Cos4Cloud CO best practice? How could these experiences help other COs? *

12. Are there any other experiences from the COs involvement in Cos4Cloud you would like to highlight? What is the outcome and benefit to the CO from this?

13. How would you summarise this COs main contribution to the Cos4Cloud project? *

14. What would you say is the main highlight from your COs involvement in Cos4Cloud? how would you describe this as an example of best practice that could be beneficial to other citizen observatories? *

15. Is there another CO you are involved in (not listed above) that has also been involved in Cos4Cloud? if yes, please state name(s) , URL and describe this involvement.

16. What is the legacy of Cos4Cloud for your CO? i.e. a new technological service, tools and experience to engage new audiences etc. Please include all that apply *

CO Survey 1 update

In this section we would like to ask a few questions to help us update the information provided in Survey 1 which was submitted in June 2020.

17. How many users does the CO have? *

18. Are there any there any testimonials, success stories etc relevant to Cos4Cloud that you would like to share? Add any links available.

19. Are there any new training and educational resources involving your CO or has your CO been used for any new educational purposes since June 2020? Please include links etc.

20. How have people used your CO? Have there been any new or emerging use cases developing since June 2020? Please describe.

21. What are the main lessons learned by your CO in terms of technology (including any integration and testing of Cos4CLoud Services)? What works or what doesn't work when creating or sustaining a CO? *

22. Email of survey contact *