BRIDGING THE GAP

BETWEEN LARGE RESEARCH INFRASTRUCTURES IN PHYSICS AND SOCIETY THROUGH CITIZEN SCIENCE

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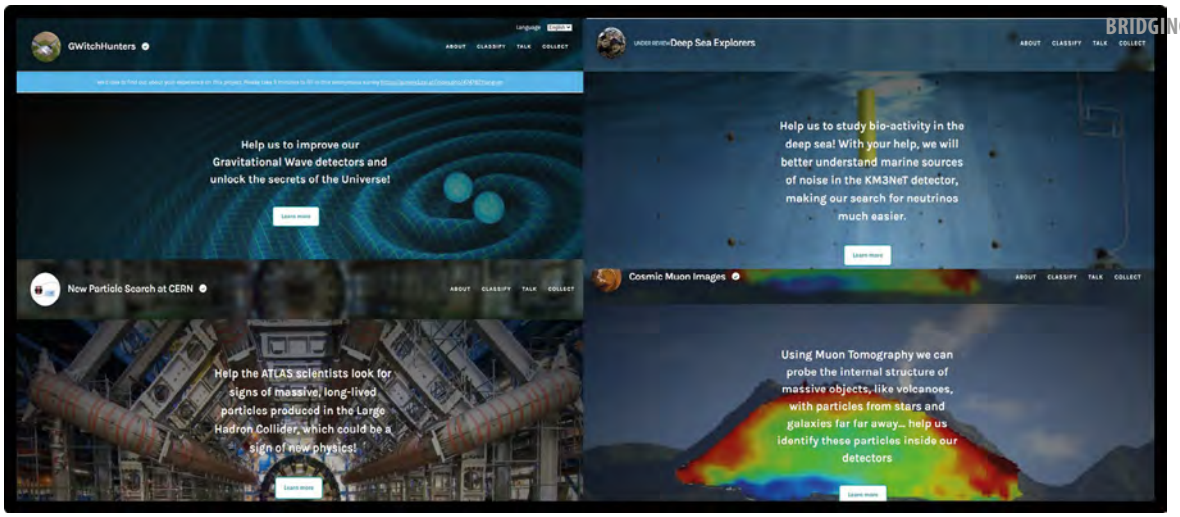
Despite the large progress of science in the frontiers of Physics and its impact to our lives, a gap between research and society is observed. In this article we discuss the potential of citizen science to help bridge this gap by both supporting scientific research and increasing society's science literacy.



◂ **FIG. 1:** The landing page of the 4 citizen science projects developed in the framework of REINFORCE. Top left: GWitchHunters; Top right: Deep Sea Explorers; Bottom left: New Particle Search at CERN; Bottom right: Cosmic Muon Images.

Scientific research in the frontiers of Physics, has provided humankind with breakthrough discoveries which help unravel the nature of the Cosmos from the very big to the very small. Unlike in the time of Galileo, when a motivated individual with a telescope could change the way we perceive the world, nowadays, research in fundamental Physics is increasing in complexity and progresses through sensitive experiments operated by international collaborations in highly sophisticated, usually public funded, Large Research Infrastructures. The operation of such sensitive large-scale experiments poses considerable challenges; scientific discovery depends critically on being able to cope with the "avalanche" of very large datasets produced by the experiments and to "mine" it.

Gap between cutting edge research and public understanding of science?

Despite the tremendous progress of science and its impact in our lives, a knowledge gap can be observed between fundamental research and society. A gap which might help spawn misconceptions about the content, context and mission of science and may contribute to citizens to fall prey to the lure of pseudoscience which spawns anti-intellectual beliefs and attitudes. The large effort taking place in education and outreach initiatives to increase public understanding of science has borne fruit, yet, while being effective in drawing students' and citizens' attention to science, outreach initiatives rarely provide opportunities for a sustainable interaction between research and society.

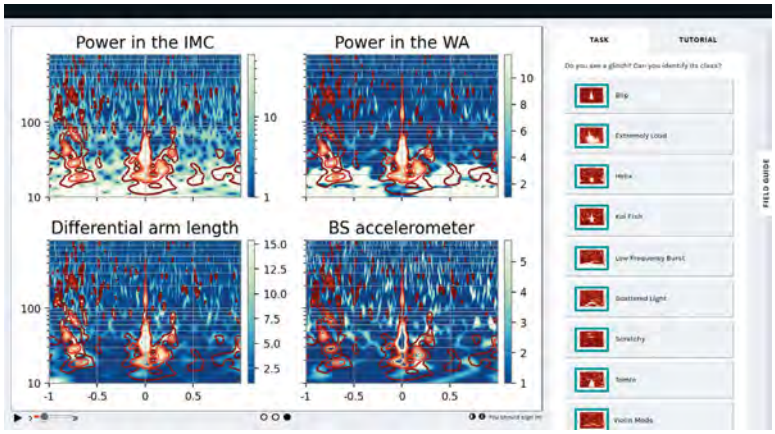
From outreach programs to citizen science

Moving beyond outreach, the emerging field of Citizen Science (CS), defined as scientific research conducted with the participation of the public [1] can be envisioned to act as the vehicle which can effectively bridge the gap between Large Research Infrastructures and society, providing the framework and tools for effective and sustainable interaction between them. Such an approach has potential to create a mutually beneficial situation; On one hand, researchers can receive help and support to refine their instruments and advance their research, as citizens' contributions may be useful in combination with or to retrain machine learning algorithms. On the other hand, citizens are trained in frontier science, they are in constant connection with researchers through dedicated communities of practice, they provide their feedback, they voice their concerns, and they actively contribute to the exploration of the boundaries of knowledge. This approach leads to several questions such as: Are citizens actually able to develop new knowledge and make a contribution in the frontiers of Physics? How do we design a citizen science project which balances social inclusion and scientific efficiency?

Research infrastructures for citizens in Europe

To tackle these questions The REINFORCE EU[1] project constitutes a three-year long exercise for the implementation of state-of-the-art level online citizen science [2] in large research infrastructures. To achieve this goal, REINFORCE, in collaboration with researchers from major European Research Infrastructures launched 4 citizen science "demonstrators": GWitchHunters[2], Deep Sea Explorers[3], New Particle Search at CERN[4] and Cosmic Muon Images[5] hosted in the online citizen science platform Zooniverse[6] and requesting citizens' support to optimize detector characterization and particle reconstruction algorithms in the Virgo Gravitational Wave detector[7], in the KM3NeT neutrino telescope[8], the ATLAS experiment at CERN[9] and the Diaphane muon detector[10] respectively. Following a contributory citizen science approach, ● ● ●

[1] https://www.reinforceeu.eu/
[2] https://www.zooniverse.org/projects/reinforce/gwitchhunters
[3] https://www.zooniverse.org/projects/reinforce/deep-sea-explorers
[4] https://www.zooniverse.org/projects/reinforce/new-particle-search-at-cern
[5] https://www.zooniverse.org/projects/reinforce/cosmic-muon-images
[6] https://www.zooniverse.org/
[7] https://www.virgo-gw.eu/
[8] https://www.km3net.org/
[9] https://atlas.cern/
[10] http://www.diaphane-muons.com/



▲ FIG. 2: Example task in the GWitchHunters project. Citizens are invited to classify a glitch and correlate it with noise in auxiliary channels of the Virgo detector

in these demonstrators, citizens were invited to collaborate with researchers and dedicate time and effort to perform classification of more than 80,000 images as well as identify and note properties of the images in question [3].

In **GWitchHunters**, citizens are invited to examine real data and classify transient noise features, "glitches", that introduce dead time in the Virgo Gravitational Wave detector according to their morphologies. Citizens are further asked to correlate the glitches with the output of auxiliary channels of the detector and identify potential malfunctions.

In **Deep Sea Explorers**, citizens are invited to Investigate the characteristics of bioluminescence in deep sea using the KM3NeT neutrino telescope optical modules. They further investigate bioacoustics in deep sea using KM3NeT hydrophones and help classify potential sources of acoustic noise in the deep marine environment.

In **New Particles Search at CERN**, citizens are invited to search for displaced vertices and do particle identification with simulated data using the Zooniverse and the HYPATIA online environment[11]. They perform a search for the Higgs boson and for long-lived particles with open data from the ATLAS experiment at CERN.

In **Cosmic Muon Images**, citizens are invited help optimise the muon reconstruction algortithms of the Diaphane Muon Detector dedicated to muography, as well as Identify extra particle strikes in the surface of the muon detectors.

In all citizen science demonstrators, a "majority logic" was implemented, requiring that the same image was classified by a minimum number of participants determined by the research team. The answer of the majority of participants was kept as the final answer and the image was retired for further analysis.

Participatory engagement activities

The large number of images, combined with the retirement limit as well as the need for careful classification of every image in order to achieve a scientifically sound result posed a series of requirements for the recruitment, continuous engagement and training of participating citizens. To achieve this, the REINFORCE team designed and implemented a citizen engagement strategy throughout the duration of the project implementation. The REINFORCE strategy describes the progressive approach for engaging citizens in the related demonstrators while at the same time describes the tasks and the expected contributions from citizens and the roles of the scientists in the process. It is a 5-step approach which involves enrichment of the demonstrators with dedicated educational resources and training materials and encompasses activities aiming to **inform citizens** - such as webinars and public talks, to **involve** them- such as virtual visits to large research infrastructures, to **facilitate collaboration** - such as challenges and competitions, to **receive consultation** - such as practice reflection workshops and **to empower them** to become ambassadors of the project in their communities- such as summer and winter schools. In order to ensure accessibility and make sure that equal opportunities are provided to everyone REINFORCE implemented a strong inclusion and diversity program, utilizing data sonification[12] in order to open up to citizens with visual and multimodal impairments. Further activities tailored to the needs of specific target groups of citizens were organized, including a Senior Citizen Science Course, a Course on Critical Thinking, dedicated workshops for students as well as dedicated art and science contests and events.

Overall, the REINFORCE team has managed to mobilise a significant number of citizens in these interventions. Throughout the duration of REINFORCE, more than 1,000,000 citizens were informed about REINFORCE throughout the dedicated campaigns and events organized and almost 30,000 citizens were involved through training activities and workshops, performing more than 1,000,000 classifications and participating in more than 5,000 discussions with researchers, with the majority of effort being done by a core community of dedicated citizens. The high levels of demonstrators' appeal during the implementation provided a significant "return of investment" as far as the time allocated by citizens: for every 1 hour dedicated by research team, 2 hours were dedicated by participating citizens!

Discussion

At this point, one has to try to evaluate what we have gained and the road that opens beyond the 4 demonstrators exposed above. Quoting the late professor Stavros Katsanevas, we have obtained a cross-fertilization of methods *e.g.* images vs tracking, effort to find the proper

[11] https://hypatia.iasa.gr/
[12] https://www.reinforceeu.eu/about/sonification-increasing-senses-increasing-inclusion
[13] https://www.asterics2020.eu/
[14] https://projectescape.eu/
[15] https://www.reinforceeu.eu/index.php/interactive-workshop-citizen-science

border between human sensitivity in reception and *e.g.* machine learning techniques; we have the effort to increase the use of human reception beyond the "optic" attitude towards sonification methods; we have established more professional methodologies of feedback, impact monitoring and interactivity assessment and finally we have reached out to different audiences with their own characteristics and needs, including teachers and students.

From the citizens' viewpoint, the first findings indicate that their participation in REINFORCE was mainly due to their own intrinsic motivation. Overall, participants' self-reported knowledge seems to improve over time, while they become more confident in understanding and being able to explain relevant scientific terms.

From the scientific standpoint, despite the extremely specialised nature of the project demonstrators, the lack of prior training and the significant effort needed, the first analysis of results of REINFORCE demonstrators showed that citizen scientists can carry out complicated tasks responsibly, with a combined performance comparable to that of a purpose-built machine-based algorithm in some cases. Whether the citizen science initiative leads to a scientific discovery such as new glitches in gravitational wave detectors or supports the improvement of a machine learning algorithm used for scientific research, the turning point is need-based implementation of citizen science: REINFORCE demonstrators' implementation showcases the usefulness of citizens' contribution.

The road ahead is promising. The work done by EU funded projects such as ASTERICS[13], ESCAPE[14] and REINFORCE as well as from scientific collaborations and individual research teams has started persuading the scientific community that Citizen Science goes beyond communication towards actual scientific contribution by the citizens. This fact can be testified by the growing number of citizen science projects in Zooniverse related to the frontiers of Physics. All the above constitute a first-class preparatory terrain to set up a roadmap program[15] for the sustainable future of this emerging field. ■

About the Authors

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References

[1] Susanne Hecker, Muki Haklay, Anne Bowser, Zen Makuch, Johannes Vogel, Aletta Bonn and Margaret Gold (2018), *Citizen Science – Innovation in Open Science, Society and Policy*. 10.14324/111.9781787352339.

[2] Helen Spiers, Alexandra Swanson, Lucy Fortson, Brooke D. Simmons, Laura Trouille, Samantha Blickhan and Chris Lintott, *Journal of Science Communication* **18(01)**, A04 (2019)

[3] Chaniotakis *et al.* (2022) *"REINFORCE-ing Citizen Science"*, Engaging Citizen Science Conference 2022 (CitSci2022), 25-26 April 2022 Aarhus University, Denmark PoS(CitSci2022)119

◂ **FIG. 3:** Examples of participatory engagement activities around the Virgo Gravitational Wave detector in REINFORCE. From informing citizens to involving them and fostering collaboration with them.