REINFORCE
REsearch INfrastructures FOR Citizens in Europe

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D2.1 Citizen Engagement Plan

Work Package	**WP2 Citizen Science Engagement Strategy**
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Deliverable Abstract

This document outlines the results of the work implemented in the tasks 2.1 to 2.3 in WP2. It summarises the outcomes of a "Scan the Horizon" effort, namely an exhaustive literature review on citizen engagement in citizen science, and the design, deployment and first results of a target group study as part of the Citizens' Survey, followed by an initial task analysis of the REINFORCE demonstrator projects. It concludes outlining the key features of the conceptualised dynamic engagement strategy in REINFORCE which will be implemented throughout the remaining project duration and coordinated by activities of WP8 (Participatory Engagement Activities).

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Terminology

Terminology/Acronym	Description
CNRS	Centre National De La Recherche Scientifique
CS	Citizen Science
CSA	Coordination and Support Action
DoA	Description of Action
EA	Ellinogermaniki Agogi Scholi Ellinogermaniki Agogi
EC	European Commission
EGO	European Gravitational Observatory
EU	European Union
GA	Grant Agreement to the project
IASA	Institute of Accelerating Systems and Applications
KPI	Key Performance Indicator
LC	The Lisbon Council For Economic
OU	The Open University
REA	Research Executive Agency
REINFORCE	REsearch Infrastructure FOR Citizens in Europe
UOXF	University of Oxford
WP	Work Package
ZSI	Zentrum für Soziale Innovation

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Executive Summary

This document outlines the results of the work implemented in the tasks 2.1 to 2.3 in WP2. It summarises the outcomes of a "Scan the Horizon" effort, namely an exhaustive literature review on citizen engagement in citizen science, and the design, deployment and first results of a target group study as part of the Citizens' Survey, followed by an initial task analysis of the REINFORCE demonstrator projects. It concludes outlining the key features of the conceptualised dynamic engagement strategy in REINFORCE which will be implemented throughout the remaining project duration and coordinated by activities of WP8 (Participatory Engagement Activities). The document tries to provide answers to questions such as: What motivates potential citizen scientists? How does the project design need to reflect their motivations and interest to achieve sustained participation and engagement of the various target groups? How does the project teams need to support citizens in to become more involved and active in the REINFORCE citizen science projects in the field of frontier physics?

Chapter 2 briefly outlines the main **target groups** of REINFORCE. A **bibliographic review** follows, providing a summary of citizens' typical needs, motivations, characteristics, and interest in participating in citizen science projects in general. It offers basic recommendations and good practices per main target group regarding the retention, engagement, and sustained participation of citizens in citizen science activities. The findings have been shared and discussed with the REINFORCE Citizen Science project teams and inform the design of the deliverable D2.2, the Citizen Science Demonstrator Template.

The REINFORCE Citizen Science projects are quite demanding in terms of their domain and therefore pose challenges for citizens to increase their confidence levels that allow for participation, and for the science team to offer the needed support and training. It is essential to investigate target groups specific characteristics, prior knowledge, attitudes, and beliefs towards science, to better understand the need for support, training, and other activities. Due to the limited options to organise physical events in the past months, an **online survey** was designed, and the first analysis of the survey will be presented in this document. The outcome of the literature review and online survey inform the needs and main challenges to be addressed in the engagement framework and plan.

Chapter 3 presents the results of an initial **task analysis** which was prepared in cooperation with the science teams. It summarizes the research goals, intended methodologies, needs for citizens participation and contribution per demonstrator project. Such analysis is the start of a reflection process that will help us shape the design and introduce the findings to the initial demonstrator design, on the how citizen can genuinely contribute and help achieve the intended research goals. The results of the task analysis are the fundament for an important part of the engagement strategy, as it is the starting point for discussion and reflection to co-design and create the projects with the citizens.

Chapter 4 introduces the **dynamic engagement framework**, a methodology that will be adapted and updated throughout the project, and that offers an organisational framework around five levels of engagement. Identifying, engaging, and recruiting enough participants as well as keeping them involved on various levels throughout the projects' duration is often a major challenge. In moving from 'inform' to 'empower', citizens can choose how to get involved in each project and its research. Each step offers different type of participation and growing influence on the research projects.

Chapter 5 offers an outlook on the upcoming tasks and describes the **central role** of D2.1 for the upcoming months, the **support mechanism** of WP8, and how we will build the **tools for an integrated REINFORCE experience** that fosters sustained retention and allows for continuously growing participation and thus contributions in all demonstrator projects.

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1. Introduction

REINFORCE aims to engage citizens in research activities of Large Research Infrastructures through citizen science activities to increase their awareness of science and positively influence their attitude towards it. The project hopes that its activities help eliminate anti-intellectual beliefs in society and provide citizens with the intellectual ammunition needed to make evidence-based decisions and become critical consumers of scientific knowledge. Even more, the goal of the project is to involve user groups in citizen science in frontier physics that would otherwise not participate in science-related activities.

To engage volunteers in citizen science projects from all targeted groups in high numbers, there are a few key questions to address: How need citizen science projects to be designed in an inclusive way, so not to connect with an exclusive set of few interested citizens? How do we engage underserved online communities with limited ICT skills and knowledge? How can we optimize an inclusive citizen science project design approach to allow citizens with visual impairments, elderly people, or citizens with low science capital to contribute to Nobel Prize Physics? In addition, issues of Responsible Research and Innovation in Citizen Science need to be considered and be integrated in REINFORCE activities.

The first important step to tackle these issues is the development of an overall Citizen Engagement Plan and its dynamic engagement framework and strategy. It lays out the methodological approach that will support an effective citizen project design and accompany the implementation of its frontier citizen science demonstrators to achieve a successful REINFORCE experience among all group of citizens.

All citizen science projects are challenged to attract and motivate citizens to dedicate their energy and time to science. Recruiting enough participants and keeping them engaged throughout the project is often a big challenge for the scientists involved. Citizen science in its nature is voluntary, meaning projects cannot offer payments or monetary rewards, so the recruitment and engagement of citizens have to focus on citizens' intrinsic motivations, and find ways to raise interest and excitement, as well as provide additional value and emphasize on the benefits e.g. for citizens' personal or professional development. The voluntary character challenges REINFORCE to acknowledge that it will have to compete for attention, that citizens are face limited resources, i.e. lack of time, or are already invested in other citizen science projects; all factors that can act as additional hurdles to achieve sustained participation.

Moreover, the success of REINFORCE is not only defined by the sheer number of people engaged in activities and events, or by the number and quality of contributions made. REINFORCE seeks to extend the outreach to an even more diverse group of people, promoting the inclusion of people to its online-based activities who have none or little involvement in science, are having various degrees of science literacy, belong to the group of elderly people, that have low ICT literacy, or are physically impaired, e.g. limited vision or hearing.

So far, online citizen science projects hosted in the Zooniverse platform display a similar pattern in terms of user engagement, as it is measured by the indicator of classifications per user over time (Reference 1). A typical Zooniverse project has a classification curve displaying a peak of activity after launch that rapidly declines, leaving a constant pedestal of users who perform most of the classification work. Intermittent spikes of activity, which can result from targeted dissemination of a project can appear in this pattern.

The REINFORCE project aims to implement a dedicated engagement strategy the ambition of which is: to engage 100,000 citizens, to sustain their engagement over time and to offer opportunities to more marginalized groups to engage without losing in terms of scientific efficiency. As a result, it is our ambition to change the "status quo" of already existing online citizen science projects.

REINFORCE offers a special opportunity: It offers involvement in Nobel Prize Physic to all citizens. Its citizen science activities provide an ideal means to "democratise science, build trust in science, and leverage the

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vast societal intelligence and capabilities to conduct excellent research and innovation" (EU COM 2020)1. Through the demonstrator projects everyone has the chance to become part of and contribute to frontier research. The projects are offering insights to the procedures of science on the highest level and gives unprecedented access to research infrastructures and data that so far was not analysed before.

In fact, REINFORCE creates a win-win situation, as it connects top-scientists directly with citizens. The science teams can receive help and support to refine their instruments and advance their research. The engagement activities serve also to sensitize scientists to the needs and expectations of citizen scientists. The scientists need to understand the needs of the REINFORCE target groups, and the engagement plan and in the future the support mechanism will play a crucial role in creating a new mutual understanding between the two sides, and in bridging the gap between science and society.

REINFORCE envisions citizen science as the vehicle which can effectively bridge the gap between Large Research Infrastructures and society. Even more, Citizen Science in REINFORCE aims to go beyond sharing computing power or classifying experimental data. It aims to be a participatory process, an amalgam of "contributory" and "co-created" citizen science, in which citizens are trained in frontier science, they are in constant connection with researchers through their communities of practice, they provide their feedback, they voice their concerns and they explore the boundaries of knowledge.

A Citizen Engagement Plan needs to outline how to involve the public in the citizen science projects. project. It aims to identify specific recommendations and approaches, as well present tools, events and techniques. The plan serves first and foremost as an internal document, nonetheless it will be made public to inform about local the projects' approach and plans for outreach, dialogue, and citizen engagement.

1 https://ec.europa.eu/info/sites/info/files/research_and_innovation/research_by_area/documents/ec_rtd_swafs_report-citizen_science.pdf

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2. Scan the Horizon - Achieving Sustained Engagement

2.1 The REINFORCE target groups

REINFORCE aims to reflect on a broad and inclusive range of stakeholders and aims to actively engage them in citizen science activities. Consequently, the project's engagement activities need to find ways to address each of these stakeholders explicitly, based on their respective needs, characteristics and possible motivation in order to involve and engage them in the project, specifically in the project demonstrators. To maximize the probability of sustained engagement in REINFORCE activities each of the stakeholder groups and actors require not only specific, custom-made means of communication, and a carefully planned and implemented timing in the interaction with the project (see WP 10), but it is important to understand the needs, motivations, preferences of the main groups of citizens that the project intends to actively involve in the citizen science projects.

In order to create a pool of citizens who support the research work of the science teams, the REINFORCE consortium needs to first better understand their needs, interests, prior knowledge and experience in citizen science and in the topics of the REINFORCE projects. The various targeted groups consist of individuals who vary with respect to age, ethnicity, gender, knowledge background, profession, science capital, potential impairments such as visual impairments, prior experience with citizen science in general and Zooniverse in particular and ICT literacy.

Consequently, the engagement plan required first an in-depth review of literature on citizen science activities and user engagement to identify a suitable action to support and sustain their engagement with the project. The main citizens group that REINFORCE hopes to engage in its activities and projects can be broadly categorized in the following groups:

- **All citizens** (Europe and beyond) **independent of the level of scientific or ICT literacy** who are interested in citizen science activities
- **All citizens** fascinated by the work of **Large Research Infrastructures** and/or interested in REINFORCE Citizen Science projects`
- Citizens with experience in citizen science projects, specifically the **Zooniverse user community**
- The **Educational Community**, which can be further distinguished:
    - Formal education (linked with schools and training institutions)
    - Non-formal education (community groups and other organizations).
    - Informal education
- Citizens with **impairments**, and
- **Elderly** citizens.

The engagement plan of a citizen science project does not only rely on quantitative user numbers alone. Real engagement is achieved by increasing the citizen scientists' participation in activities and their loyalty to the REINFORCE citizen science projects. A support mechanism that specifically offers concrete support and tools for each group will be described in more detail in D8.1: The REINFORCE Community Support Mechanism.

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2.2 Bibliographic Study

A bibliographic review was conducted addressing citizens' typical needs, motivations, characteristics, and interest in participating in citizen science projects in general. It was the fundament to formulate the first basic recommendations and good practices per main target group regarding the retention, engagement, and sustained participation of citizens in citizen science activities. Findings that concern the design or functionality of the online platform have been shared and discussed with the REINFORCE Citizen Science project teams and inform the design of the deliverable D2.2, the Citizen Science Demonstrator Template.

The bibliographic desktop research addressed the following research questions relevant to REINFORCE:

- What motivates citizens overall in an online citizen science project in Zooniverse?
- How can citizens' motivation be sustained over time?
- How can inclusion and scientific efficiency be balanced?

2.2.1 Motivation to join (online) citizen science projects

The analysis was performed based on the existing bibliography regarding motivations and engagement of users with a focus on Zooniverse projects (references 1,3,4,5,7 – see chapter 6). One needs to take into consideration that the results summarized below refer to users who have participated in at least one Zooniverse project and thus might not fully apply to newcomers in Zooniverse. The categorization presented here can help identify motivations relevant to the projects in the field of Physics that REINFORCE intends to create. Table 1 gives an overview of citizens' motivations that have been identified and proposes a series of steps to be followed per motivation category at different stages of the project to achieve maximum user engagement.

Table 1 Citizens' motivations and relevant recommendations

Addressed User Motivation	Recommendations for Project Launch	Recommendations for the duration of the Project
Contribution to original scientific research	• Highlight the importance of citizens' involvement, the science case, and the ongoing research of demonstrator in a welcome message • Highlight in a welcome message/short video. • Make the experience as authentic as possible for citizens. • If demonstrator uses data currently being collected make sure to highlight it. • If demonstrator searches for effects in data that have not been analyzed yet by a scientific team, make sure to highlight it. • Make sure that citizens and experts have open channels of regular communication.	• Issue regular status updates in form of newsletter to inform users of overall progress of the project • Identify good practices of citizens' engagement and potential impacts (if any) of their work.
Discovery, novelty, and competition	• Highlight the novel character of the project in the landing page • Highlight that this is an open field for discovery • Promote the dialogue with scientists working in cutting edge experiments.	• Release data in batches so that users may anticipate them. • Infuse data with "golden events" (real or simulated) to motivate them to classify even mundane images. • Issue classification challenges with new datasets
Interest regarding the Content	• Motivation for content depends on users' interest in said subject. Therefore, language used should be simple to address a broad range	• Pop-up messages referring to scientific highlights, technological

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	of users, but not oversimplified to estrange most dedicated users. • Interdisciplinarity and impact to society should be highlighted on par with science case in the landing page. • One could choose messages according to the users' profiles: "e.g. Student, teacher, citizen or so" • Initiate relevant discussion in "talk"	innovations, historical trivia, impact on society, or other • Increase complexity of content with increasing nr of classifications.
Learning	• Offer initial educational resources (pdf, ppt, video, micro-MOOC, links) to accompany project but not necessary to implement it. • Design and offer a training strategy for users. • Initiate relevant discussion in "talk" for questions and answers.	• "Reveal" more educational resources as time goes by. • Add short self-assessment quizzes.
Self-Gratification	• Make sure that you highlight the fact that the citizen science experience can be self-gratifying from the beginning of the project.	• Pre-arrange supportive messages after user is passing a successful threshold of classifications. • Recognize individual accomplishments publicly. • Offer badges or other incentives.
Teaching	• Offer educational resources for teachers on how to use the proposed demonstrators in the classroom.	• Pilot activities in the classroom. • Organize competitions for students. • Oorganize teacher training and citizen training workshops.
Greater involvement in the project	• Organize visionary workshops to identify citizen needs and priorities. • Be ready to adapt projects to citizen needs. • Set up communication channels for citizens and experts.	• Organize regular webinars to present project progress to citizens. • Organize regular practice reflection workshops in the framework with different groups of citizens. • Focus on building online communities of practice.
Self-efficacy	• Offer citizens perhaps the opportunity to skip a classification if they don't feel comfortable with it. • Make sure you reveal to citizens the majority logic of Zooniverse projects to relieve classification anxiety.	• Make sure that you offer support and feedback to citizens regarding their scientific output.
Feedback	• Make it clear where and how citizens will receive feedback in the landing page of each demonstrator.	• Offer personalized help. • Make sure that a scientist from will be available to answer questions of citizens with satisfactory response rate.
Social Status/Community	• Offer citizens opportunity to engage with leading scientists. • Make sure to offer some sort of token to citizen scientists (e.g. a certificate). • Establish citizen recognition mechanisms both online and in situ: as an example, citizens may participate in podcasts with scientists.	• Organize events where citizens can participate actively, and high-profile scientists will be there. • Apply citizen recognition mechanisms (e.g. offer further roles in community according to user engagement).

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		• Empower citizens to organize their own events.
Altruism	• Appeal to citizens' affective domain.	• Recognize citizens' contribution and highlight their help if/when it is important.
Having fun	• Make content engaging, presentable, easy to use, perhaps add gamification figures.	• Make sure that users keep their interest, learn new things, discover rare events etc.

2.2.2 Sustaining Citizen Scientists' Motivation Over Time

Motivations change with time, depending on the project type and with user group. Furthermore, increased project participation has impact on users' learning, and supports the creation of more tightly knit groups of citizens to perform dedicated tasks. This study focuses on projects hosted by the Zooniverse platform, as they will share several characteristics with the citizen science demonstrators of REINFORCE.

Factors influencing citizens' sustained participation in Zooniverse projects (References: 1,3,4,5,6,7)

The Zooniverse platform

Most Zooniverse projects follow a typical power law curve of classifications per user and display a decay curve of overall classifications vs time. Zooniverse offers a specific project format, great infrastructure, know-how and a broad range of users. However, the inclusion of a citizen science project on a successful citizen science platform website such as the Zooniverse does not guarantee high levels of engagement alone.

Communicating with users

Sustainability of project engagement relies on projects maintaining continuous communications with their audience.

Learning throughout the participation process

Learning about scientific topics occurs and is correlated with further engagement in the project. Someone who wants to learn more about science, may watch the tutorials and then not proceed to classifications. Learning occurs even if the motivation to learn is low among participants and if projects were not designed with learning as a primary goal. Learning can be supported through interactions among volunteer and scientist participation in online discussion forums and other communication channels. Recruited volunteers were more engaged than volunteers who were not recruited.

Table 2 Recommendations to achieve sustained participation of citizens in online citizen science projects

Factors influencing Sustained participation	Recommendations
Communication with users	• Offer online communication means as well as opportunities for face to face communication
(User) Training / Learning opportunities	• Add initial educational resources to accompany project but not necessary to implement it. • Design a user training strategy per Demonstrator. • Initiate relevant discussions for Q&A.
Citizens' sense of making a difference and their contribution to science	• Classification anxiety main reason to abandon working in a project. It arises because of the tension between how the users think of science and how the Zooniverse projects make them experience it. We will need to explain them how Zooniverse uses a majority logic. • Personalized feedback to citizens scientists / users need to assured of the quality of their work. • Scientific outcomes and contributions of citizen scientists should be recognized and publicized.

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	• Citizens may be intimidated by scientists. Communication between scientists and citizens needs to increase. • Add direct feedback mechanisms, as lack of response / feedback may lead to disengagement.
Strategy of releasing incrementally (partial) data sets to users	• A project with a large, pre-existing data set could partition their data for gradual release, to encourage more frequent volunteer interaction. • Combination of high publicity / communication / dissemination to increase overall outreach and achieve deeper engagement vs time. • Balance between competitiveness and inclusion. Tightly knit communities of citizen scientists might produce great science output, yet this might exclude individuals who are unable to offer a regular time commitment and increase anxiety and pressure on the ones that do not exactly fit the curve of productivity. Both groups should be encouraged to participate, and this implies that a multilevel approach should be adopted in the citizen science projects. • Inform in events about the possibility to find "exotic events"
Regular interventions vs time	• Organize "Classification Sprints": Short term challenges to keep them motivated. • Connect these activities with dissemination campaign(s) and participatory events
Users' length of engagement	• Make the platform "addictive", e.g. through the timing of classifications (they may come in quick succession). • Make the interface presentable with nice graphics, etc. • Tasks should be optimized to fit into busy schedules. • Offer a variety of tasks, from short, atomized tasks to long term tasks that required dedication. • Take advantage of "dead time" of user (e.g. while commuting in a train) and create mobile-use friendly projects. • Make it easy for citizens to return, while still feeling like valued participants.
Users' depth of engagement	• Tasks should be able to satisfy all levels of users, from novice to advanced. • Introduce a multilevel approach: Identify different user profiles and organize different/targeted actions: "journeys" and adjust complexity of tasks accordingly.
Users' prior science background	• Make sure that the language and content will appeal to users of different science backgrounds.

2.2.3 Balance of Inclusion and Scientific Efficiency

A central goal of REINFORCE is to find a balance between scientific efficiency and inclusion. This means that the project activities seek to engage a broad range of stakeholders into the project activities, empower them and sustain their engagement throughout the project. To achieve that, REINFORCE projects need to be designed in such way that are universally usable, but also interesting and plausible for all our users.

This challenge needs to be further divided in the following sub-questions:

3.1. What are the Horizontal Considerations one needs to consider?

3.2. How do we engage the key REINFORCE target groups?

Horizontal Considerations

The horizontal considerations discussed in this section can apply to all target groups and offer insight for an overall approach towards citizen engagement (References 2,8,9,10).

Table 3 Horizontal considerations for balancing inclusion and scientific efficiency and proposed recommendations.

Factors to Balance Inclusion and Scientific Efficiency	Recommendations

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Adopting a Universal Project Design	• Provide a multi-layered design that will answer to the needs of novice and advanced users, • Provide clear pictures with an easy to use interface that elderly people will be able to use. • Content should be adapted to the needs of the users as well. • Choosing different 'journeys' for different users might be effective (for example, student, teacher etc.).
Including a broad range of users in the beginning of the project	• Involve citizens from the beginning of the project and collect their feedback (through surveys, visionary workshops). • Track down marginalized groups in preparatory workshops to identify their needs, goals and main motivations.
Maintaining users' diversity throughout the project	• To support inclusiveness, we need to gain the trust and keep constant contact with our users. • Organize dedicated meetings and/or events to hear their opinions in the talk forum or other discussion media.
Designing citizen science projects with a variety of requirements in terms of users' skills to achieve wider stakeholder participation.	• Break down tasks in different parts, employing different skills that different kind of people are good at. • Design project to need various and different kinds of skills (and thus tasks) in the projects
Investigating the impact of equipment, media and interfaces	• Needed equipment might make it difficult for specific groups of citizens to contribute. One needs to design treatments to simultaneously be independent of digital technologies and cost effective. • Organize usability testing for different types of users and adapt their feedback to our project design.
Enhancing collaboration and communication between stakeholders	• Offer opportunities and tools to users to collaborate within the tasks themselves. • Offer regular means of interaction between users and project leaders both online and in situ.

Target group specific considerations

Educational community (References 11, 12, 13)

One of the main target groups for REINFORCE is the educational community which broadly consists of students (all ages with focus in high school students); teachers (mainly as mediators and multipliers who will act as the project's ambassadors to the students); school leaders (who will be able to support the implementation of REINFORCE in their whole school in terms of becoming: REINFORCE schools). Table 4 summarizes the main considerations for the educational aspects of citizen science as they have been identified from bibliography, the bibliographic inputs, and the recommendations for REINFORCE.

Table 4 Considerations and recommendations for the engagement of the school community

Factors affecting the engagement of the educational community	Recommendations
Connection of citizen science projects to the school Curricula	• Tie project tasks to the curriculum, even at the textbook level • Offer levels of advancement, both within projects and between projects.
Balancing Scientific goals and educational learning outcomes	• Offer concrete learning outcomes: Cognitive Domain: • Project specific learning: Disciplinary knowledge related to the topic of the project • (Increased) Scientific literacy • Other knowledge and skills unrelated to the main topic of the project. • Affective domain

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	• Support the increase of sense of meaning of school learning and science courses. • Personal development – expanding interests and social networks • Identity change • Cultivate the feeling of playing a key role in the process which may in turn increase science motivation
The availability of Educational Resources	• Plan educational resources for the teachers to support the extra effort required to engage in citizen science. • Create adaptable lesson plans and support teachers creating their own lesson plans. • Make sure that educational resources are easy to use and embed them to the projects for students who engage with the project activities outside the classroom. • Develop collection of how-to videos for using citizen science in schools.
Supporting teachers' active involvement	• Engage teachers in small professional learning communities supported by project experts. • Develop fresh ideas for teachers who want to try something new each year. • Encourage peer to peer sharing, provide a user-friendly platform for teachers to connect with each other, share experiences, get feedback, and cooperatively develop lesson plans. • Design and offer relevant teaching materials to ease their work in connecting them to school curriculum. • Develop a platform for teachers to connect with scientists who support school projects • Empower teachers to become creators of content.
Supporting students	• Produce a learning pathway (e.g. "student journey") in the REINFORCE projects' interface that will be more student friendly and engaging. • Organize the journey according to their difficulty to include both novices with interest in science and more advanced students. • Organize a series of participatory activities that will bring students closer to the work of large Research Infrastructures in Physics and connect them directly with scientists. • Adopt an event-based approach: School-based or initiated events, such as "A visit to a research institute"; " A virtual visit to a research institute"; " The visit of a scientist to the school"; "An online Masterclass"; " A competition"; "An exhibition for students"; "A REINFORCE day". • Organize informal / non-formal education events, such as competitions, classification marathons, year-long projects dedicated to students. • Foster teamwork: Identify tasks that students should collaborate to perform beyond simple classification schemes if possible, perhaps gravitating on interdisciplinarity.
Reaching out to the educational community as a whole	• Establish "REINFORCE schools" which can be selected to act as ambassadors of REINFORCE to local society and help build opportunities for further parental involvement. • Establish cooperation with museums and other informal education institutions and engage them as key partners. • Offer schools the opportunity to present their work in REINFORCE in outreach events such as the Researchers' Night.

Adult Citizens (References 14,15,16,20,22,24)

Adults citizens are one of the main target groups of REINFORCE users. As their motivations overall have been discussed in Research Question 1 and the factors that could help sustain their participation in a Zooniverse - related project in Research Question 2, this section focuses mainly on further sub-categorization of this target

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group. The main recommendations identified by research questions 1 and 2 will apply to the generic adult target group as well. For the needs of this study, we explore further the following sub-categories of adults: adults with low level of science background; adults with high level of science background; adults with low ICT literacy; senior adults.

To achieve such a differentiation, science background needs to be identified. To offer citizens with varying science backgrounds a meaningful citizen science experience, it is proposed to adopt a multilevel design which offers a scaling of the complexity of the associated tasks. The novice and experts have different ways to solve physics problems. Experts fall into learning plateaus where in the case of data analysis they stop exploring the data[17] and only focus on identifying events[17]. With low learning curve exercises both populations may augment skills[18], whereas high learning curve exercises may help the most committed expert users to invest more on the project.

Engaging Adults with strong science background

In general, adults with strong science backgrounds and teachers are assumed to have many aspects in common, besides the specific needs for teachers as far as their teaching practice is concerned. It is our assumption that Zooniverse user are usually high science background adults who are deeply engaged in the different projects, and thus we point back to Research Questions 1 and 2 for a further exploration of this category.

As an overview, it is proposed that strong science background adults should be:

- Empowered to have a more active roles in the discussion forums. They should be offered the chance to obtain higher level roles (such as the role of a moderator), get accreditation and recognition.
- Mobilized to become REINFORCE "representatives" and support participatory engagement activities, manage user online communities, among others.

Engaging Adults with low science background

In order to include and engage adults with comparatively low science background in REINFORCE activities and projects, the following recommendations can be offered:

- In your online project design, offer tasks of varying complexity which do not discourage this target group to engage.
- Offer them space to interact and speak up. Make sure that you do not overwhelm them with complex terminology and encourage their participation in discussions online and offline and be responsive to their concerns, ideas and opinions.
- Make sure you value and accredit their contribution.
- Make sure that their interaction with experts is constructive for them and does not drive them away due to the perceived high status of the experts.
- Make sure that you will offer companion audio-visual educational material that uses a comprehensive vocabulary and present the associated topics in a way friendly to the layman.
- Make sure that the science and outreach experts that will engage with citizens are aware of the barriers and difficulties they might face and that they are properly trained to support the engagement with this target group.

Design a course/workshop for citizens that:

- Focuses on ideas, not facts, phenomena or formulae[14]. Connect it to philosophy, nature of science, ideas such as: time and space; what are things made of; Human senses vs "signals out there" etc.
    - Focuses on discussion rather than instruction
    - Is regular (e.g. a science café) to sustain the users' engagement.

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- Allows direct interaction between experts and citizens and thus supports the deconstruction of the notions of elitism that some citizens might have regarding scientists, as well as the support the bridge of knowledge gap between experts and non-experts.
- Offers the opportunity for various age groups to mix.

Such workshops could be designed and offered for all target groups, while mixing citizens of varying science background might be beneficial in terms of peer learning, if the workshops are effectively moderated.

Senior (elderly) citizens (References 20,22,23,24)

The group of senior citizens (typically, citizens who have retired), is an important, yet under-represented group in the field of science education and outreach so far. The REINFORCE consortium strongly believes that resources should be invested in the engagement of senior citizens with citizen science because:

- Offering them training and support could help them make better informed decisions. As the economical and productivity model has caused a skill gap and economic need gap, this population is largely left behind.
- It might help keep elderly people engaged: Retirement can lead to social isolation, which is linked to health problems, not only due to lack of support but also due to the feeling of loneliness. Being part of a community can have tangible benefits for elderly people. Example of such a community is this of amateur astronomers.
- Social engagement may delay the onset of Alzheimer's disease and other forms of dementia and slow down cognitive decline. Engaging the brain throughout life strengthens the neuronal network so it can better withstand the effects of age, thus supporting community wellbeing (cognitive reserve theory).

Table 5 Considerations and recommendations for the engagement of senior citizens.

Senior citizens' engagement considerations	Recommendations
Considerations for the overall design of online citizen science projects for seniors	• Produce printed material: Seniors prefer printed material, in their native language, with well-defined pictures, and need enough time to absorb the content • Create training materials that focus on ideas mainly and not on technical stuff: Many are intrigued by the wonders of modern science but not necessarily at a technical level: it is ideas, principles, philosophy and history that might mainly intrigue them • Make sure that the interface you utilize will have images easy to see and letters easy to read
Considerations for senior citizens with low ICT literacy	• Organize Intergenerational training activities20 with younger people as coaches in school-like settings. Provide opportunity for iteration of younger generations and senior generations to coach
Considerations relevant to the needs of senior citizens	• Design workshops considering that it might take longer to understand things for elderly people • Consider that that even though backgrounds of senior citizens may vary, they still have a strong interest in the philosophical questions of modern science (how was the world made? What is matter made of?) • Consider the social dimension of the senior citizens' potential participation and offer them initiative to socialize. Science might not be their main interest, but it would be of interest to them to participate if this helps them socialize more. • Consider that elderly citizens may have more time available due to retirement status. It has been observed that many, especially with strong science motivation and sturdy scientific background tend to participate very actively in community science activities

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	• Senior citizens who may already have a technical or scientific background, may tend to share or overshare their knowledge. Workshop moderators need to be patient and moderate discussions wisely. • Take into account that elderly citizens tend to favor in-situ discussions. They like to go to a place at a regular rate, listen to somebody talk, discuss, and go back home. They also tend to develop bonds of trust with whomever they choose to listen to. To engage them, it is recommended to organize regular face to face meetings such as science cafes; meetings in public libraries; local senior and community centers. • Connection with scientists could be made in situ or online through initiatives such as "Skype a Scientist"(Reference 24)

Citizens with visual or multimodal impairments (References 25,26,27,28,29,30,31)

REINFORCE aims to focus on the target group of visually or multimodally impaired citizens. Considering that visually impaired people often outperform sighted people, REINFORCE introduces data sonification to support them to exercise this advantage of theirs for the pursuit of new scientific knowledge. This section outlines main recommendations regarding this specific target group. A separate section with recommendations on an accessible Human – Computer Interaction (HCI) design developed by Johanna Casado, Wanda Díaz-Merced and Beatriz García.

The basic needs for the participation of this target group of users are:

- Access to interpersonal communication with members of the academic community.
- Access to multisensorial educational material
- Equal Access in tasks
- In the case of the students and young adults for the treatment not to augment the disability in front of peers
- Equal Access in amount and quality of information
- Allowing the person to bring their disability experience

Table 6 summarises recommendations made:

Table 6 Considerations and recommendations for the engagement of citizens with impairments

Considerations for citizens with visual or multimodal impairments	Recommendations
Equal access in amount and quality of information	• Online citizen science projects need to embed software that reads text on a PC screen. The interface used for the project design needs to be friendly to users with all types of impairments. • One should make sure that visually impaired citizens who participate in online activities already have received training on how to access information and browse through the web or at least to master keyboard access • Need to facilitate activities which do not to depend only on desktop, tabletop-digital access e.g. text book may be created and in the progress of skill acquisition for data analysis in the text book instructions on how to navigate online will be displayed, or radio lessons
Equal access in educational materials	• Materials need to be adapted to several different mediums and the time taken to deliver content needs to be extended to allow the target audience time to engage with complicated theories and ideas. • The educational material adapt a multi-mode approach that reinforces the key learning points and gives the learner the option of different methods. • Dedicated lesson plans that include haptic material are needed: 3D printouts along with sonification are very important means to this end.

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	• Learning outcomes need to be well defined and tailored to the needs of this target group. Citizen science tasks should be on par with these learning outcomes.
Equal access in tasks	The following considerations need to be considered when organizing in-situ engagement activities targeting this group. • The needs of the learners with Visual or multimodal impairments require close interaction with a scientist-presenter in a group of no bigger than four participants. • Throughout presentations, speakers should make sure to offer companion haptic material to the audience. • The range of visual impairments in this audience group is usually broad, with total sight loss uncommon and the requirements of text size and materials very person dependent. • Scientists should be trained in visual impairment awareness, sight guiding, their speech should be comprehensive and descriptive and audio description and presentation of a tactile narrative should be linked to the desired learning outcomes. • It is suggested to bring an approach that will allow the person to use their own modalities and not to have to invest time adapting to new ones, a place of interaction where the treatment welcomes the person just as he/she is.
Accessing citizens with visual and multimodal impairments	• The main need is to approach the organizations serving peoples with disabilities to gain their trust. If the main organization trust you then you will earn the trust of the disabled/impaired people in the country it will also be easier to figure out what is needed for mobility, surprise cases, and integrate the organizations in the local work for equal participation in science in their countries.

2.3 Getting to know the audience – The Citizen Science Survey

The success of an effective engagement strategy depends on how well it reaches and engages its intended audience. Therefore, it is very important to fully appreciate the characteristics of the target groups it aims to involve. What are their motivations and interests? How would they prefer to be contacted? What are they type of events they are most likely to become involved in? What type of support will they need to actively engage in the projects? What are the barriers and constrains or preferences that need to be considered?

Even more, for projects aiming to have citizens partake in research of large research infrastructures and in fields that touch Nobel Prize Physics, it is also important to understand the audiences' attitude towards 'science', their perceptions and biases, their existing level of (scientific) knowledge related to the topics of the REINFORCE demonstrator projects but also their basic understanding of key scientific terms.

An important focus of the online-based Citizen Science Survey was to support the collection of data on the key characteristics and motivational factors of potential citizen scientists. The survey was designed to find out what drives users to participate and thus evaluate which aspects need particular attention not only in the design features of the demonstrator projects but also how to focus engagement activities on the interests or needs of the respondents.

The literature review described in the previous chapter has given important indications and recommendations to what generally the most essential factors for engagement, participation and motivation are in citizen science projects. While the literature review provided important general information about motivation and sustained participation in citizen science projects, the survey intends to find out more about what our users are interested in doing and what they already know about the work of the participating research infrastructures.

Even more, wanted to test the recommendations and compare the motivations with our audience. Unfortunately, it was not possible to organise physical events that would have allowed us to test and discuss

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overall motivations with various target groups. This is while we organised within a quite demanding time frame on online survey in which we have tried to collect data to test our approach and the recommendations. In additions, it was an important test to understand our outreach potential and target groups especially within our own networks.

2.3.1 Initial Survey Analysis

This survey aimed to identify the potential target groups of REINFORCE, explore their characteristics and investigate:

a. their interest to contribute in REINFORCE;
b. their primary motivations in order to participate in REINFORCE projects, following the outcomes of the bibliographic study;
c. the factors that can affect their sustained participation in the REINFORCE citizen science projects.

This survey is an ongoing process and the results reported here can be considered preliminary, yet enlightening.

Sample Size

The sample consists of 263 citizens (37.1% male; 62.9% female) with the following distribution of ages. The majority of the participating citizens have a strong educational background, having acquired at least a Bachelor's degree:

Table 7 Age distribution of survey respondents

Age Groups	%
25-34	10.23
35-44	27.65
45-54	39.02
55-64	18.18
Other	4.92

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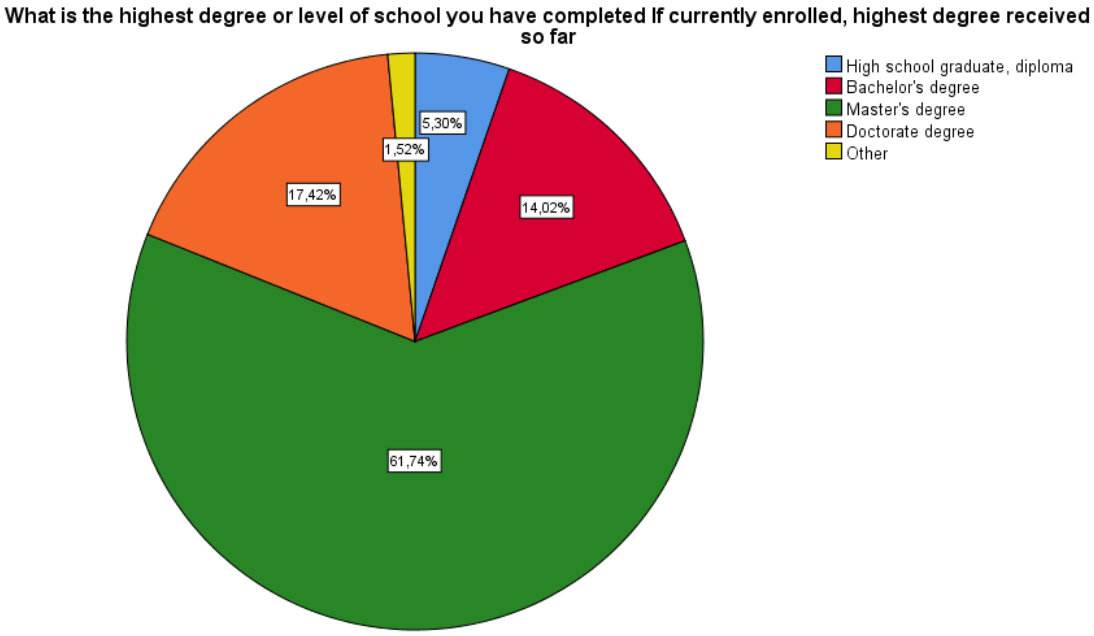

Figure 1 Highest formal education degree of survey respondents

Out of these participants 86% are currently employed. 65.9% have been or currently work in a research center, university, or academic research. 36,4% state that their profession is related to Natural Science and 31.8% are currently teachers in primary and secondary school.

Participants' awareness of citizen science

A series of questions were asked to participants to gauge their awareness and prior experience with citizen science. Most of the participants (57%) are aware of citizen science. 28.5% of the participants have participated before in a citizen science project and 55% of these have participated in projects related to Physics/Astronomy.

Participants' disposition towards science

The survey participants were asked to state if they see themselves as "very into science", if they "quite like science", if they are "not that into science" and if they "really dislike science". More than 90% of the participants answered that they are "very into science" or "quite like science". Regarding the societal benefits of science, more than 75% of the participants agree or strongly agree that science has a positive impact to society, while only 6% disagree or strongly disagree that science has benefitted them personally.

General knowledge about science

In order to assess the participant citizens' general knowledge about science, a series of questions had been asked with the following options as answers: true, false, not sure.

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Table 8 Questions to assess participants' general knowledge about science

	True (%)	False (%)	Not Sure (%)
Spacetime can ripple	63.88	5.32	30.80
Astrology is an important part of science	28.52	66.92	4.56
Electrons are smaller than atoms	87.45	8.75	3.80
Humans, as we know them today, evolved from earlier species of animals	79.47	10.27	10.27
Light travels faster than sound	94.68	3.80	1.52
Antibiotics kill viruses as well as bacteria	13.69	73.38	12.93
It's possible to detect cosmic particles that are passing through the earth	76.81	3.42	19.77
Cosmic radiation can help visualize the inside of huge solid objects, such as mountains	43.35	13.69	42.97
All radioactivity is manmade	3.04	86.69	10.27
The continents have been moving apart for millions of years	93.16	3.80	3.04

The participants' answers are considered satisfactory taking into account their educational background, with the exception of the 10.27% "false" answer regarding the evolution of species and the 28.52% "true" answer to the question : "Astrology is an important part of science". These two questions are considered as indicators through which the overall science literacy of participants could be evaluated.

Questions such as "Spacetime can ripple" or "cosmic radiation can help visualize the inside of solid objects, such as mountains" have a high percentage of participants who are not "sure", something expected taking into account the advanced character of these topics. With the increase of statistics of the survey, safer results will be able to be obtained.

Self- Reported familiarity with terms of scientific vocabulary relevant to REINFORCE

Going beyond general science questions, the REINFORCE Citizen Survey includes a list of vocabulary items relevant to the subject content of the REINFORCE citizen science demonstrators. The vocabulary items address Physics concepts of varying sophistication, concepts about the detection principle utilized in the respective research infrastructures as well as observables relevant to specific REINFORCE demonstrators. Participants were asked to report the familiarity they have with these terms through a 1-4 Likert scale (1: Not familiar at all; 4: Very familiar). **The list of items can be found in the Survey Report in the Annex**.

We observe that the vocabulary items: "Vertex", "muon", "bioluminescence", "glitch", "muography", "neutrino telescope" and "interferometer" have the lowest scores in terms of citizens' familiarity with them. The citizens' familiarity per demonstrator specific vocabulary items can be found below.

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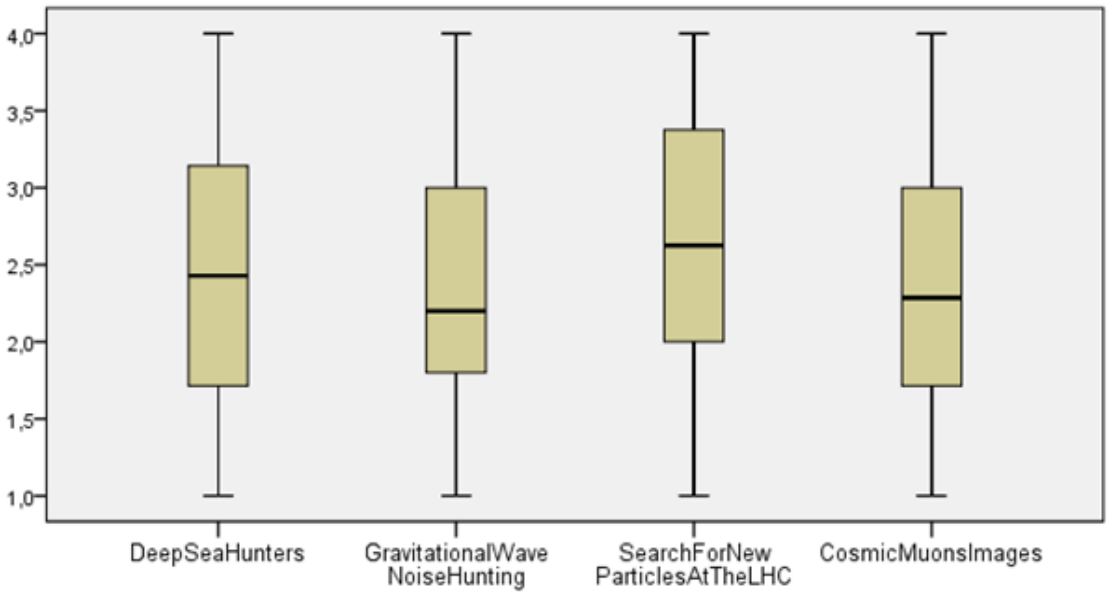

Figure 2 Citizens' vocabulary familiarity per REINFORCE demonstrator

We observe that the vocabulary familiarity per demonstrator is above average with the one related to CERN displaying a higher trend than the others. With the increase of statistics of the survey, safer results will be able to be obtained.

The survey also asked to state how confident respondents are to explain to a friend what the three research infrastructures, that the project's demonstrators correspond to, do. The findings indicate that while more than 65% of the respondents feel confident to explain what CERN does, only 27% feel confident to explain VIRGO and 13% KM3NeT respectively. These findings, combined with the results of vocabulary familiarity per demonstrator, indicate that the majority of the topics introduced by REINFORCE are quite novel and might be difficult to understand to the respondents. In this framework, **REINFORCE needs to focus specifically on the offering support to introduce and explain the work of each LRI in the context of each demonstrator**, offering high quality educational resources (e.g. tutorials) and organizing participatory activities that will support citizens' training in these issues.

Interest to contribute to REINFORCE Demonstrators

Having identified teh sample in this survey, we proceed in the identification of their interest to contribute to the REINFORCE demonstrators, their main motivations as well as the factors they consider important in order to sustain their engagement. The participants of the survey were asked to state their interest to contribute to each REINFORCE demonstrator, answering a 5-point Likert scale questionnaire (1: Not interested at all – 5: Very interested). The results per demonstrator can be found in the Annex. It can be observed that respondents' **interest is high** and that **no significant changes** are observed between demonstrators. The overall interest of respondents to contribute to REINFORCE is presented in the following histogram.

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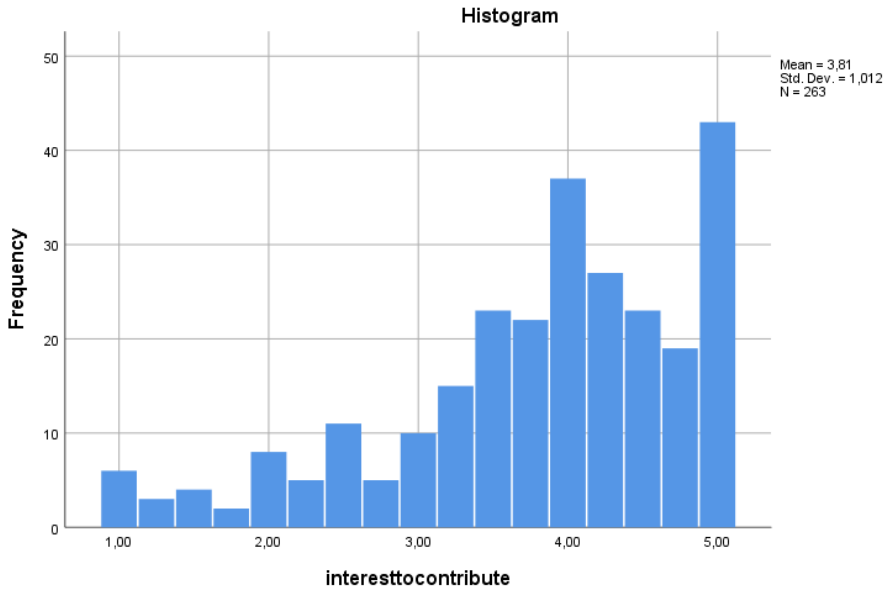

Figure 3 Respondents' interest to contribute to the REINFORCE demonstrators.

Further analysis demonstrated that **no significant differences** are observed with respect to **gender**. Citizens with stronger science background seem to have an overall higher inclination to contribute to the REINFORCE projects of the order of 13%. With the increase of statistics of the survey, safer results will be able to be obtained.

Citizens' motivations to participate in REINFORCE

To investigate the participants' main motivations to participate in REINFORCE, a series of proposed motivations coming from the bibliographic research have been identified. See **Table C in the Annex**. Participants answered a 5-point Likert scale questionnaire (1: Strongly Disagree – 5: Strongly Agree), the results of which are summarized below in Figure 5

Overall, all the primary motivations of citizens, identified by our bibliographic research seem to be present within the sample of our survey with citizens agreeing on most of them. We observe that on average, motivations relevant to social standing and sharing with colleagues and social media don't seem as important as "helping to make discoveries" and "expecting to learn a lot about cutting edge science" which are the main motivations of the respondent citizens.

Factors that sustain citizens' engagement

This section identifies the main factors that are expected to affect citizens' sustained engagement in REINFORCE. The participants answered a 5-point Likert scale questionnaire (1: Strongly Disagree – 5: Strongly Agree), the results of which are summarized below.

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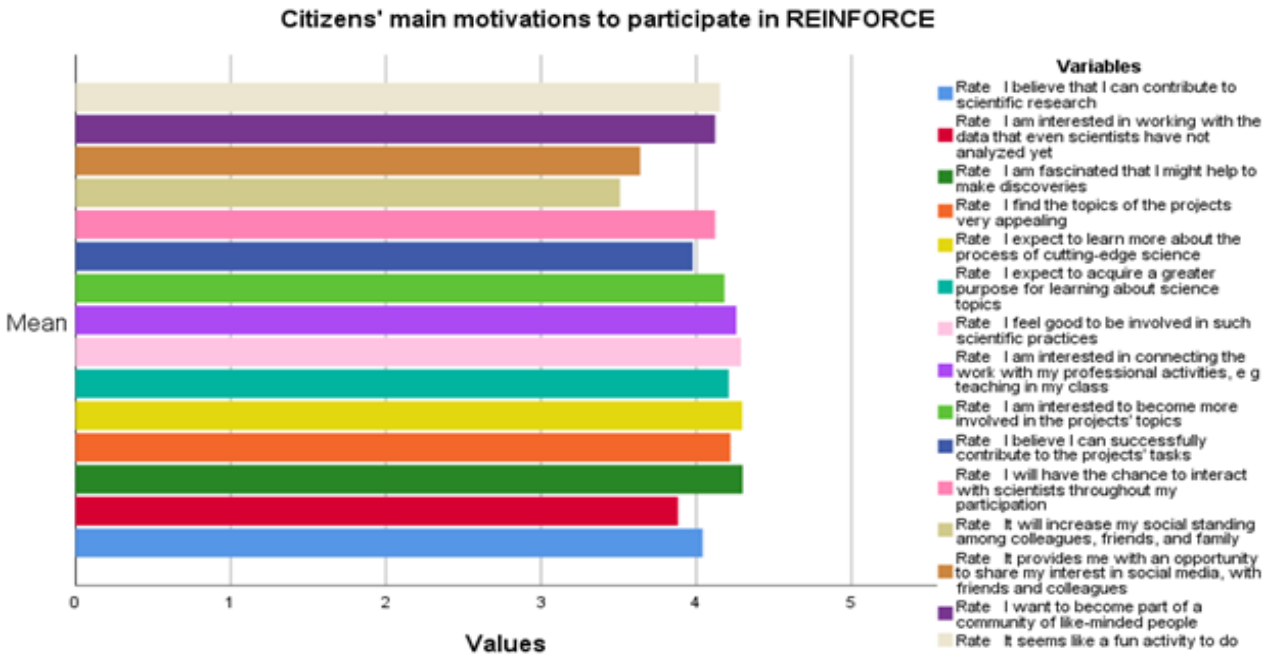

Figure 4 Citizens' main motivations to participate in REINFORCE

Overall, all factors are considered quite important or more, with the factors: "**Getting feedback**", "**Understanding the scientific impact of their work**", "**Receiving training**" and using an "**interface that is easy to manipulate"** can be considered as the most important messages. With the increase of statistics of the survey, safer results will be able to be obtained.

2.3.2 Summary of the findings of the present survey

The sample so far consists mostly of respondents of age 25-54 years old with advanced educational profiles, with good disposition towards science and on average a prior exposure to citizen science. This demonstrates that the sample so far **is not inclusive**, yet it shows who are the users that are most likely to participate in REINFORCE. As the goal of the project is to enhance its inclusion, the engagement strategy needs to address these features and focus on providing activities in which scientific efficiency and inclusion can be balanced.

Most of the topics introduced by REINFORCE are quite novel and might be challenging to get involved in by the respondents. In this framework, REINFORCE needs to **focus explicitly on providing increased educational resources and activities for** its demonstrators, offering scaffolding and support, organizing participatory activities that will support citizens' training in these issues.

Public perceptions of fundamental research can be improved as it can be seen from answers relevant to "how scientific astrology is" or about "obscure aims of Large Research Infrastructure". Throughout its engagement strategy and its educational content, REINFORCE is prepared to work towards this goal.

The findings indicate that the citizen engagement strategy of **REINFORCE must address all the proposed citizen motivations horizontally** as their importance is overall equal to the citizens.

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Table 9 The main findings of the citizens' survey in REINFORCE

Identification of participants
• The majority of the participating citizens have a strong educational background, having acquired at least a Bachelor's degree • The majority of the participants (57%) are aware of citizen science. • 36.4% of participants work in fields relevant to Natural Sciences. • The majority of the participants answered that they are "very into science" or "quite like science". They agree or strongly agree that science has a positive impact to society and to them personally. • The majority of participants answered adequately a series of general science knowledge questions, with the exception of a question regarding astrology and whether it is scientific in which more than 28% answered yes, indicating a misconception regarding this issue.
Familiarity of participants with the science, mission and work of Large Research Infrastructures (LRI) in Physics
• The participants were mildly familiar with vocabulary items relevant to the demonstrators of REINFORCE. • More than 65% of the respondents feel confident to explain what CERN does to a friend, only 27% feel confident to explain about VIRGO and 13% about KM3NeT respectively. • The respondents have correctly assessed that the main aim of large research infrastructures in Physics is to understand the universe from the very small to the very big and have correctly identified the mission of betterment of society. • There seems to be a knowledge gap in a minority of the respondents who indicate that LRI's main mission is the production of military applications, communication with aliens, opening portals to other dimensions and most notably, that the main mission is "Hidden because they don't want us to know what is happening".
Interest of participants to contribute in REINFORCE
• Respondents' interest is high and that no significant changes are observed between demonstrators. No significant differences are observed between genders, while more scientifically oriented citizens display higher inclination to participate.
Participants' primary motivations to contribute in REINFORCE
• On average, motivations relevant to social standing and sharing with colleagues and social media don't seem as important as "helping to make discoveries" and "expecting to learn a lot about cutting edge science" which are the main motivations of the respondent citizens. No significant changes are observed with respect to gender. • Participants with prior experience in citizen science are motivated by the opportunity to contribute to scientific research, by the opportunity to work with new data and feel more confident than the average to contribute in the project tasks. • Participants with strong scientific background display the same characteristics, with the addition that they "feel good to be involved in scientific research and are fascinated that they might make discoveries." • Participants who seem to have anti-scientific beliefs display lower confidence than the average that they can contribute in science and higher motivation to share their results with their peers and increase their social status.
Factors that can sustain participants' engagement
• All factors selected by the bibliography are on average equally important to the respondents.

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- "Getting feedback", "Understanding the scientific impact of their work", "Receiving training" and using an "interface that is easy to manipulate" can be considered as the most important factors that can influence their sustained engagement.

2.4 Existing Initiatives

Over the past yeast, numerous citizen science initiatives, platforms, support pages and project have been created, as the concept of citizen science is blooming across scientific disciplines. There are various Citizen Science platforms all around the globe that collect, publish, or present current and past citizen science projects and invite volunteers to take part in them. In the frame of the "Scan the Horizon" activities, we have identified several of the largest CS platforms and CS advice/support sites. Specifically, the aim was to probe over the coming months their existing support measures for achieving and sustaining a high engagement level of the volunteers. The results will feed into the Community Support Mechanism of D8.1.

2.4.1 Citizen Science Platforms and Knowledge Hubs

Zooniverse is the world's largest and most popular platform for citizen science project activities. The platform enables research and has currently more than one million registered users and volunteers who support and assist professional researchers to carry out their work. Projects in Zooniverse aim to enable research that would not be possible, or practical, otherwise. Zooniverse research results in new discoveries, datasets useful to the wider research community, and many publications. https://www.zooniverse.org/

SciStarter is an online community dedicated to improving the citizen science experience for project managers and participants. Over 3,000 projects and events are searchable by location, scientific topic, and age level, and members can track their contributions and provide feedback. SciStarter also supports researchers in managing projects, including best practices for engaging participant partners. https://scistarter.org/

EU-Citizen.Science is an online platform for sharing knowledge, tools, training and resources for citizen science. The platform aims to support the mainstreaming of citizen science, and build on the growing impact of citizens participating in research across the full range of scientific enquiry, by supporting the sharing of knowledge, know-how, and experience between anyone doing or wanting to do citizen science. https://eu-citizen.science/

Citizen Cyberlab is developing methods and studying motivations for new forms of public participation in research. They integrate researchers from a diversity of backgrounds – history, informatics, learning, linguistics, medicine, physics, psychology and more, and initiate projects and events that encourage citizens and scientists to collaborate in new ways to solve big challenges. From online crowdsourcing to in-person hackathons, we are exploring and expanding the limits of citizen science and human computation. https://www.citizencyberlab.org/

Spotteron is providing services for science projects and institutions with a strong focus on design, technical professionality and reliability. They are creating custom

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online solutions for science and Citizen Science applications. They have long term experience in design, media and web technologies comes together with our focus on innovation to create advanced solutions for science communication and interactive Citizen Science apps. https://www.spotteron.net/

CitSci.org supports research by providing tools and resources that allow the customization of a scientific procedure on the internet. CitSci.org provides tools for the entire research process including: creating new projects, managing project members, building custom data sheets, analyzing collected data, and gathering participant feedback. They are a partner of **Citizen Science Central** and connect CS coordinators with resources to help guide them in starting citizen science programs. https://www.citsci.org/

Citizen Science Center Zurich aims at engaging academic scientists and the public in next-generation citizen science projects, tackling problems in different fields of science and society, from fundamental physics to human health. It is providing resources, expertise and technical know-how to develop, set up, and run citizen science projects. The Citizen Science Center Zurich The Citizen Science Center is run jointly by the University of Zurich and the ETH Zurich. https://citizenscience.ch/en/

The **Center for Citizen Science** in Austria was established in June 2015 by the Federal Ministry of Education, Science and Research. It serves as a service and information centre, which supports both scientists and practitioners in the development and implementation of citizen science projects as well as the science ministry in the conception and implementation of appropriate funding measures. The Young Science program is a focal point in the Center for Citizen Science and offers Austrian schools and research institutions a wide range of opportunities to get in touch with each other and work together. https://www.zentrumfuercitizenscience.at/en/

2.4.2 Citizen Engagement - EU Projects (SWAFS)

CIMULACT - http://www.cimulact.eu/

CIMULACT's main objective was to engage citizens and stakeholders in the co-creation of research agendas based on real and validated societal visions, needs, and demands. CIMULACT built on the principle that the collective intelligence of society gives Europe a competitive advantage and strengthens the relevance of the European science and technology system. CIMULACT established genuine dialogue between thousands of citizens, stakeholders, scientists and policy makers visions and scenarios and produced valuable suggestions for research and innovation policies and topics.

CIMULACT produced "**The Inspiration Catalogue**"[2] which presents methods for conducting activities for public participation. It showcases methods for one aspect of public participation in science: the design of research programmes. However, the methods presented in this catalogue can also be used in completely

CS Track - https://cstrack.eu/

[2] http://www.cimulact.eu/wp-content/uploads/2018/04/D5.1_Inspiration-Catalogue-for-consulting-different-groups-compressed.pdf

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The aim of CS Track is to broaden the knowledge about Citizen Science and the impact Citizen Science activities can have. CS Track will do this by investigating a large and diverse set of Citizen Science activities, disseminating good practices and formulating knowledge-based policy recommendations in order to maximise the potential benefit of Citizen Science activities on individual citizens, organisations, and society at large.

3. Task analysis – Informing Demonstrator Design

Over the past years there has been a rapid growth in the number of online citizen science projects. Most of these projects involve the participants in rather simple tasks (i.e., micro-tasking). However, as the literature review above has shown, citizen scientists are motivated by the opportunity to contribute to real science and by recognition for such contributions. Accordingly, REINFORCE seeks to involve volunteers more deeply in the science of the project: Not just collecting or processing data, but also taking part in further data analysis and new determination of classification types. REINFORCE aims to involve volunteers in more advanced tasks to demonstrate that citizen science is not exploitative, i.e., an exploitation of the volunteers by project scientists. The opposite is true: the involved science teams aim to expanding access to science, by allowing participants to see and discuss about the data they share.

To successfully include volunteers more deeply in scientific research requires careful consideration of the kinds of projects offered, the scientific goals to be achieved, how to coordinate contributions, and arrange tasks within project. Accordingly, the task analysis of WP2 intends to break the complex citizen science project into a series of smaller sections or topics, so the research team can define better their actions and overall framework for the demonstrator project. Understanding all the aspects to be considered will assist in identifying any tasks that may need extra support or instruction for the citizen scientists.

The following tables outline and present the initial ideas for the REINFORCE Demonstrator projects. Each demonstrator team was asked a set of questions which were built on the quality criteria catalogue for Citizen Science projects by the Austrian Citizen Science network (www.citizen-science.at) and it was further complemented with questions relevant and specific to REINFORCE. The questionnaire was organised along with different topics:

- Scientificity,
- Participants,
- Collaboration task,
- Communication, and
- Ethics.

The questionnaire was sent to the different demonstrator teams for further input and open issues discussed during an online interview for more clarification. The current task analysis forms the basis for the upcoming engagement activities. The ideas of the science teams will be presented and discuss with the potential citizen scientists. The tasks analysis if a first step and now needs to be discussed, presented and worked on with the citizens in the overall engagement process. The needs and specific interest of the citizens will be consulted and their feedback integrated to create updated projects and/or define the support activities that citizens are relying on.

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Table 10 Task Analysis – Gravitational Noise Hunting

Scientificity			Participants			
Scientific question / hypothesis	**Scientific methods**	**Expected new knowledge**	**Target groups**	**Requirements**		**Preparation**
				Infrastructure	**Skills / Knowledge**	
• Classify the noise features (e.g. glitches) • Classify and characterize also other noise features • Identify impact of auxiliary channels on the h(t) Goal is a dataset of classified noise features for Virgo and possibly the other interferometers	• Machine learning approach using the time-frequency representation of the noise in the Gravitational Wave interferometers • To be converted to images or sounds and to be used as input for the classification	• Better knowledge of the noise in Virgo • Improving the detector range and increase the number of detections	• People interested in gravitational wave science • All age groups, from students to elder people. • Involving children could be an interesting possibility. • Interest to implement a "sonification" part to involve visually impaired people	• Access to computer • Internet connection	• Knowledge of the different appearance of noise features, • More game-oriented activities for children. • For visually impaired people converting the glitch data to sounds	• Set of training webpages • Online videos • Learning by doing (in the sense that they will learn as soon as they will classify more things) • 1-hr initial training (e.g. video tutorials, later dedicated F2F training meetings)
Collaboration Task(s)						
Added value		**Need for CS**	**Involvement of Citizen Scientists**	**Foreseen task(s) and workflow**	**Nature of the task**	**Time involvement**
Citizen Scientists	**Science Teams**					
• Learn about the various details on how the noise can impact on a scientific measure, i.e. the observation of gravitational waves • Be updated with the status of the detector	• Updated dataset of the noise features • Training of the machine learning algorithm to use for discriminating glitches from real signals	• The basic ingredient for training the machine learning algorithms is to have a dataset of labelled samples • This could only be achieved with the help of dedicated people that look at the noise features and classify them	• Search for a topic and formulation of research questions (e.g. statistical properties of these glitches and their general behaviour) • Data collection (e.g. labelling of glitches)	• Users will see a representation of the noise in a specific timeframe • Will identify, encircle all the relevant features, tag them • Results in database of labelled features for machine learning algorithm	• Contribution task(s): the citizens contribute to the project with performing tasks (identifying, labelling, etc.)	• 1-hr initial training (e.g. video tutorials, later dedicated F2F training meetings) • Citizens will then work independently and start classifications. • There is no minimum time
Open Science		**Communication**			**Ethics**	

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Data	Location of Data	Project to Citizen Scientists	From CS to project	Feedback on Progress	Fundamental ethical values	Inclusion, diversity, gender equality
• Data is already public under the policy of the LIGO and Virgo collaboration • Data made public after a certain amount of time after the data has been acquired. • Discussing if labelled data will be published	• Research output can be made public through a specific website	• Demonstrator and documentation will be promoted through social accounts • Outreach tasks of Reinforce. • Contacts to schools in Italy and abroad • Newsletter	• Publish contacts on website, e.g. emails • Zooniverse contact form.	• Updates on a blog / website • Scientific publications based on the outcome of the classification • Posts on the university and EGO portal	• Participation for all people / Avoid any form of discrimination • Contribution will be used in the sole interest of advancing knowledge of gravitational wave physics	• Provide access to scientific data, showing that science is inclusive

Table 11 Task Analysis – Deep Sea Hunters

Scientificity			Participants			
				Requirements		
Scientific question / hypothesis	Scientific methods	Expected new knowledge / improved understanding	Target group	Infrastructure	Skills / Knowledge	Preparation
• Study the biological activity in the vicinity of the detectors • Analyse light signals from bioluminescent organisms and acoustics signal from cetacean mammals • Classify characteristic emission patterns and their variation ==> Results compared with machine learning algorithm ==> Each class of events will be used in interdisciplinary projects.	• Sequences of time series data from the optical modules & sequences of acoustic time/frequency spectrogram data from the acoustic hydrophone will be presented. The citizen scientist will be asked to classify the various the 'waveforms' observed • In parallel computer algorithm will do similar classification and compare with the citizen scientist classifications. • For both cases, correlations with other	• The bioluminescence data has never been studied to such an extent previously, so this is a completely new research topic, and everything done will be new knowledge. • For the acoustic data, a previous study has been performed on a relatively limited dataset. We hope to extend to a larger sample and develop better classification methods.	• Citizen scientist tasks can be performed by essentially anyone with good visual skills. • Data could be sonified, opening it up to the visual impaired. • Sonification of optical data is envisaged	• Access to computer / speakers • Internet connection • Access to the Zooniverse website. • No specific software needed.	• No special scientific knowledge is required.	• For each task, a tutorial will be presented when the participant enters the corresponding module. • It will describe the event format and explain the meaning of the different parameters. • It explain the scientific method underlying the task.

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	parameters will be investigated.					
Collaboration Task(s)						
Added value		**Need for CS**	**Involvement of Citizen Scientists**	**Foreseen task(s) and workflow**	**Nature of the task**	**Time involvement**
Citizen scientists	**Science Teams**					
• Sensitisation to the scientific method • Learn about basic concepts of data analysis and the principles of machine learning. • Appreciation of the biodiversity in the deep sea, even at such extreme depths. • Contribution to pioneering studies.	• The classifications are not so obvious. Scientists will develop machine learning algorithms whose outputs will be compared to the results obtained by the citizen scientists.	• The optimisation of machine learning (ML) techniques for the identification of different classes of events in the data collected by KM3NeT. • This approach relies on identification of the most relevant parameter to be used in the ML algorithm, a task requiring manpower and dedication.	• Data analysis • Different levels of participation based on work and experience • Participants to discuss the comparison with the machine learning algorithm	• Task 1: Event classification • Task 2: Peer reviewing of the classification • Task 3: Search for new parameters • Task 4: Identification of most performant discriminating parameters	• Contribution task(s): the citizens contribute to the project with performing tasks (identifying, labelling, etc.)	• Tasks 1 and 2 can be performed on blocks of events of a specific size (ca. 15 minutes). • The participants can process as many blocks as they want.
Open Science		**Communication**			**Ethics**	
Data	**Location of Data**	**Project to Citizen Scientists**	**From CS to project**	**Feedback on Progress**	**Fundamental ethical values**	**Inclusion, diversity, gender equality**
• New datasets will be periodically released on the Zooniverse platform. • Real-time is not envisaged because of the time needed to preprocess the data into a Zooniverse-compatible format.	• Classified events will remain accessible and be reinjected into the classification scheme (task 2). • Summary information will be presented (statistics of events, classifications, parameters, etc.) • Statistics of participants profile • At the end of each participant's session, a summary is shown.	• Deep-Sea Hunters will be promoted part of the KM3NeT Collaboration. • Website and social media platforms of KM3NeT • Events organized in schools or in front of a young audience, potentially in the framework of Masterclasses.	• A "question" page on the website (contact form) will be provided. • Zooniverse contact form.	• Project webpage and updated in real-time • Statistics at the end of each participant's session • Results will be used to collaborate with marine biologists	• Participation for all people / Avoid any form of discrimination • Participants will not have any information on the profile of other users.	• Global statistics will be promoted to communicate on the diversity of participants.

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Table 12 Task Analysis – Search for new particles at the LHC

Scientificity			Participants			
Scientific question / hypothesis	Scientific methods	Expected new knowledge	Target group	Requirements: Infrastructure	Requirements: Skills / Knowledge	Preparation
• Explore data collected from the Large Hadron Collider of CERN to search for new elementary particles and physics mechanisms that would extend our knowledge of particle physics beyond the well-established Standard Model, • Highlight revised directions for future research, • Provide clues for some of the open scientific questions (e.g. the origin of dark matter).	• Search for evidence of undiscovered particles among a sample of proton-proton collision data recorded with ATLAS • For this purpose, the event-display and visual-data-analysis software HYPATIA will be used. • The project will finally be integrated into the Zooniverse platform.	• While the Standard Model Higgs boson has been discovered in July 2012, there are several theories Beyond Standard Model (BSM), such as supersymmetry. • Citizens will look for new particles predicted by such BSM theories; their search can lead to the discovery of one such particle which will be proof of new physics.	• Citizens above 15 years old, of any gender, profession etc,. • Same target group as the Zooniverse platform • The nature of the research (which is visual data analysis) makes it difficult for users with visual impairments	• Access to computer / speakers • Internet connection • Access to the Zooniverse website. • No specific software needed.	• All necessary knowledge will be provided with tutorials • Additional bibliography will be included • Familiarity with basic high-school-level physics concepts, such as the structure of matter is necessary	• Detailed instructions for each stage will be given. • (Online) Training on event signature examples produced by simulations of the new particles will be offered. • F2F training will be only done in very few cases during visits to schools.

Collaboration Task(s)						
Added value		Need for CS	Involvement of Citizen Scientists	Foreseen task(s) and workflow	Nature of the task	Time involvement
Citizen scientists	Science Teams					
• Introduction to methods of scientific investigations, • Active engagement in “real” searches for new phenomena, • Experience the work done in large scientific infrastructures	• The scientists will compare the citizens’ findings with theirs and may find ways to improve their search-for-	• Algorithms looking for new particles are usually tuned to look for specific signatures. • People can notice unusual data that would be missed by algorithms.	• Data analysis and interpretation • Publication and communication of results (i.e. citizens are actively involved in the	• Citizens are the end-users • The comparative analysis of citizens’ results versus ATLAS scientists’ results, at higher-level tasks, may lead to the	• Contribution task(s): the citizens contribute to the project with performing tasks • Collaborative task(s): the tasks	• Citizens can perform searches anytime • Searches will be offered in increasing difficulty.

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	discovery algorithms.	• With aggregation of data from Citizen Scientists, histograms can improve algorithms.	writing of the publication).	improvement of the algorithms used by the latter.	are performed together	• Time will depend on the number of "events" they wish to investigate.
Open Science		**Communication**			**Ethics**	
Data	**Location of Data**	**Project to Citizen Scientists**	**From CS to project**	**Feedback on Progress**	**Fundamental ethical values**	**Inclusion, diversity, gender equality**
• The data used is already publicly available as a part of CERN Open Data (http://opendata.cern.ch/), and represent a significant portion of the overall LHC-recorded data.	• The results of the investigation will be made available • A comparison of both datasets will be performed • Any possible findings will be published. • There will be no personal data collected	• The projects will be advertised on social media and their tracking aspects may provide information about the demographics of the citizens engaged in the searches. • All of these steps will be taken care of by the Zooniverse platform.	• Direct guidance through the Zooniverse portal, as well as the project's social media. • Contact to communicate any unexpected features through Zooniverse	• Feedback will be available through social media channels (e.g. Facebook, Twitter) • Through dedicated forum on Zooniverse	• The data collection will be performed through the Zooniverse platform	• Everyone is encouraged to participate in the search for new particles. There is no exclusion of any group

Table 13 Task Analysis –Interdisciplinary studies with Geoscience and Archaeology

Scientificity			**Participants**			
Scientific question / hypothesis	**Scientific methods**	**Expected new knowledge / improved understanding**	**Target group**	**Requirements**		**Preparation**
				Infrastructure	**Skills / Knowledge**	
• Demonstrating the imaging capability & techniques	• Application of muography, similar to the X-ray imaging techniques	• These new methods open access to imaging capabilities of large structures, natural or	• All citizens, including young children at school. • Depending on	• Access to computer / speakers • Internet	• All necessary scientific knowledge will be provided with tutorials	• Direct interaction with scientists during online masterclass • Prototype of

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(mueography) of naturally produced muons • Ideas to improve tracking algorithms • A "muon challenge" will ask for solutions to inflate artificially the rate of detected muons to improve the quality of the images.	but with different particles • There are 2 types of muography methods : absorption muography (comparison of the measured muons flux with the expected muons flux) and scattering muography (measure the deviation in the particle's trajectory before and after the target).	anthropic, and may be used in different applications: non-invasive controls in industries, archaeology, volcanology etc.	format of the data (tracks coordinates of the penetrating particles), they may be sonified and addressed to visually impaired	connection • Access to the Zooniverse website. • No specific software needed.	• Abit of particle physics and the basic features of geometry (straight line definition, geometry in space).	exercises will teach the methods, e.g. an exercise such as "imaging" of a school.
Collaboration Task(s)						
Added value		**Need for CS**	**Involvement of Citizen Scientists**	**Foreseen task(s) and workflow**	**Nature of the task**	**Time involvement**
Citizen scientists	**Science Teams**					
• Introdcution to the cosmic rays basic features as • a probe of the atmosphere parameters and • as a probe of any target (buildings, underground layers etc.).	• Possibility to perform simple data/simulation comparisons and images by comparing measured to reference muons fluxes.	• The muons imaging science involves atmosphere physics, geomagnetism etc. to particle physics, geosciences techniques • Gathering all expertise at the largest scale is a clear advantage to upgrade the method.	• Method design • Data analysis and interpretation	• Method design: develop tracking algorithms, include a priori knowledge to the physics case before analysis, • Interpret produced images • Perform diagnostic given their expertise.	• Contribution task(s): the citizens contribute to the project with performing tasks • Collaborative task(s): the tasks are performed together	• Images interpretation may require 1-2 hours depending on the images • Integration of information requires collaboration with scientists • Development of tracking algorithms is more challenging
Open Science		**Communication**			**Ethics**	
Data	**Location of Data**	**Project to Citizen Scientists**	**From CS to project**	**Feedback on Progress**	**Fundamental ethical values**	**Inclusion, diversity, gender equality**
• For public data involving volcano monitoring the confidentiality may be preserved.	• Real pictures corresponding to the muons' images come from public data. • Same stands for the real	• The diverse target groups should be addressed through the project's international network in different	• Direct contact to project team via email. • Contact to communicate any	• The participants will receive feedback through the COMICs Newsletter and the	• Imaging capabilities with societal impact (natural hazards, industrial risk mitigation etc.) or to	• The project is fully inclusive without any discrimination of any kind. The demonstrator

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• images displayed on the Zooniverse platform. • The data for the tracking analysis should be provided as downloadable files on the platform.	trajectories of muons among the cloud of points proposed on the platform.	languages and the Zooniverse platform.	unexpected features through Zooniverse	Zooniverse platform e.g. the “muon chat room” (discussion forum).	address natural/industrial hazards (e.g. volcanos, industries).	recording data, which will be accessible also for people with visual impairments through the sonification process

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4. The Methodological Framework for Citizens' Engagement

The results of the bibliographic overview and the first analysis of the online survey show that there are some challenges that REINFORCE needs to specifically address. To offer more inclusive citizen science in frontier physics, the project consortium needs to **broaden its outreach** and scope, having to find better access to **involve a greater range of citizens in more geographical areas**. After all, **citizen science projects depend on attracting all citizens and keeping them motivated to dedicate their energy and time to science and the specific project**. Identifying, engaging, and recruiting enough and a diverse range of participants as well as keeping them involved on various levels throughout the projects' duration is obviously going to be a major challenge. Too often, a small core group of volunteers is responsible for most of the input to a project[3], and prompt feedback from the teams behind the project is important to keep activity levels high.

Furthermore, in our understanding "engagement in citizen science" means not only to ask citizen scientists to contribute data or invest time, but to go beyond: to **share their experiences**, **pose questions,** and being able **to interact directly and discuss the findings with scientists** from the project teams. Ideally, a strong citizen science engagement strategy and its activities will lead to a **growing participation** and **increased loyalty** to the activity.

The cornerstone of any successful engagement strategy in citizen science is the citizens. However, to get them involved in the REINFROCE demonstrator projects, and to ensure a long-term sustained participation, their needs, motivations, and interests need to be addressed and answered. It will require ongoing and consistent effort from the whole project to design, create and offer a variety of appealing opportunities to get engaged in. The survey and the first vision-building workshops demonstrate already a very high interest of citizens to participate and contribute to new fields of citizen science. The work of WP2 has already identified important factors that could support and sustain engagement.

The engagement strategy of REINFORCE needs to facilitate volunteer citizens to move from passive involvement (i.e. getting informed) to active involvement (i.e. contribution), ideally empowering them to utilize an **integrated REINFORCE experience** for their own personal or professional development. REINFORCE intends to produce a toolbox, i.e. mix of activities that appeals to and invites all targeted user groups to join and participate. User groups may need different services or types of support, such as: tutorials, workshops, trainings, contests, or competitions, but also should be engaged over postings and contacts in social media management, campaigns, and much more. In other words, the project needs to offer an **integrated REINFORCE experience** that fosters sustained retention and allows for continuously growing participation and thus contributions in all demonstrator projects.

The previous chapter 3 "Task Analysis" has outlined the expectations of the science teams in terms of project design and citizen contribution. The challenge will be now to balance the scientific needs and expectations with the willingness, motivations, interest, and abilities of the citizens to get involved in the scientific research proposed. The engagement strategy needs to facilitate the exchange of ideas between the citizens and the science teams to enable the important balance.

Throughout the REINFORCE project it will therefore be essential to organise this process that will allow to question the design of the projects, gather and assess the various needs from both sides, and finally define the citizen scientists' expectations and bring them in balance with the needs of the scientist of the LRIs. This participatory consultation process will bring together and bridge the gap between the citizen scientists and the research teams to create the optimal mix of support services both sides need and require.

The following chapters will detail an overall strategy and showcase examples of types of events and support mechanisms that will be created and implemented under WP8.

[3] De Moor, T., Rijpma, A. and Prats López, M., 2019. Dynamics of Engagement in Citizen Science: Results from the "Yes, I do!"-Project. Citizen Science: Theory and Practice, 4(1), p.38. DOI: http://doi.org/10.5334/cstp.212

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4.1 Reorganising the Experience: Sustained Engagement in Times of SARS-CoV-2

When REINFORCE started in December 2019, the world looked much different, and so the project started also with a different outlook, planning to implement various **in situ participative events** in all REINFORCE consortium countries as part of the core strategy of engagement. However, given the ongoing public health crisis caused by the SARS-CoV-2 pandemic, it is no surprise that more and more onsite events, conferences and workshops are being cancelled, postponed, or switched into virtual events. Instead of joining indoor physical workshops or meetings that allows for personalised interaction, participants are currently and increasingly choosing to attend webinar sessions, live-stream events, or watch pre-recorded content straight from their homes or offices. This is also affecting projects such as REINFORCE, and we are challenged to adopt the plans regarding the engagement activities in the upcoming months and most likely even years.

The distinctive value of face-to-face interactions will certainly not be able to be fully replaced or replicated by virtual events. Nonetheless, these are times when "going virtual" has to become an integral part of any outreach and engagement strategy. For each event that was planned to take place onsite, we now need to (re)think and (re)design such an event so that it can be offered online. The challenge for online based events are not too different from onsite event, but require different techniques and tools: how can one ensure that attendees are engaged throughout the (online-based) event?

Already, the project and its partners have started discussing for online alternatives to this sudden change. WP2 is especially challenged to re-consider the original approach, develop (partially) a new strategy, and consider alternatives to mobilise and prepare volunteer communities so that they are interested and able to join our citizen science projects. The engagement strategy in REINFORCE needs to open the door to new ways of engagement and to connect (with) people online, reducing health risks while still gathering the crucial information from the potential citizen scientists to design the most appropriate projects that attract interest and sustain participation from a broad group of different people.

Onsite events provide unique benefits such as face-to-face interactions based on human relations, however the opportunities offered by online-based events can be significant and have the potential to outweigh the disadvantages. A virtual platform can be accessed from anywhere in the world by an attendee as long as he or she has a computer or mobile device and an Internet connection. Virtual events can more easily extend their outreach beyond the project countries at a truly global scale. Generally, they are easier and faster to set-up, can more easily be repeated and provide more flexibility for attendees to follow. From live-streaming to pre-recorded videos, online surveys, and feedback sessions, etc. almost all activities can be restructured to work online, while still offering engagement-driving experiences that extend beyond a computer screen.

REINFORCE has already shifted to online-based events and virtual meetups, offering a first **Online Webinar (1 June 2020)** introducing the REINFORCE project to the European Research community and to the broad public of potential citizen scientists. Furthermore, in July 2020 the project has organised dedicated online-based **Visionary Workshops** (**21/22 July 2020**) and **co-organised** an **Online Summer School** specifically for educators **(13-24 July 2020)**. Still, the original engagement strategy needed to be more profoundly adapted. While online events have been foreseen from the very beginning in REINFORCE, these types of events have now to become the core strategy. REINFORCE and SARS-CoV-2 therefore present a unique challenge and learning opportunity to identify the best formula for every event type, onsite or online.

4.2 The Levels of Engagement in Citizen Science Projects

The options available to scientists for engaging citizens and other stakeholders in a research project that chooses the participatory citizen science approach are little known. Researchers are usually not aware what they can offer to citizens throughout the course of a project. Despite the increasing popularity and rise of citizen science projects over the past years and the ongoing efforts to make research more open and inclusive, there seems to be little guidance on how to do effectively engage citizens in research.

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However, there are lessons to be learned from other initiatives that try to facilitate a participatory design and public engagement, such as public participation practices in government and public decision-making processes. The International Association for Public Participation has created a framework to assist with the selection of the level of participation that defines the public's role in any public participation process (see IAP2 Spectrum of Public Participation).

For REINFROCE, we believe that this spectrum can be built upon and if adapted to the purposes of citizen science projects and research, it can provide an overall methodological framework not only for REINFORCE activities, but for citizen science engagement in general. In its core, the framework recognizes five types of engagement, and while they were developed for other purposes, they work well in a citizen science and research context:

Table 14 The Five Levels of Public Engagement in Citizen Science

Inform	Researchers inform the public and explain their main objectives. They assist the public to understand the needs and opportunities, as well as the research goals of the citizen science project.
Consult	Researchers get into a dialogue with the public, listening to and acknowledging the expressed ideas and concerns, needs and motivations of citizens.
Involve	Researchers are co-creating (some aspects of) the research project, and planning their activities ensuring that citizens ideas, concerns, motivations are directly reflected in the project design.
Collaborate	Researchers are partnering with citizens who help them collect information, share their contributions. The scientists incorporate citizens' findings, observations, and comments into their research work.
Empower	Researchers provide resources, advice and assistance to citizens who further utilize CS projects and their activities and integrate them for their own purposes and research.

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Table 15 REINFORCE Citizen Science Engagement Framework

Increasing Level of Engagement & Participation Of Citizen Scientists In CS Projects

Level	Inform	Consult	Involve	Collaborate	Empower
Citizens Engagement Level	Citizens are being informed about the research needs, intentions, goals, and foreseen activities. They will understand how they can assist researchers to achieve them.	Citizens can provide feedback, share their initial ideas, or concerns on the citizen science project design and activities. They will express their own interests and motivations.	Citizens work with scientists to ensure that their needs, ideas, concerns, and aspirations are consistently understood and integrated in the project design and activities.	Citizens implement and contribute to the CS project. They are keeping direct contact and discuss observations directly with researchers and other citizen scientists.	Citizens are being assisted by scientists in making use of the CS activities to inform others, train citizens in scientific skills, or in conducting their own research.
Researchers Obligations	Researchers inform the general public. Various target groups will be contacted and informed separately and according to their perceived interests.	Researchers start a dialogue, acknowledge the shared ideas and concerns, needs and motivations of citizens. They explain the benefits of becoming involved and what contributions citizen scientists can make to the research work	Researchers ensure that citizens ideas, concerns, motivations are directly reflected in the project design. They are providing feedback on how input influences CS project design and activities.	Researchers collect contributions and incorporate findings, observations, and comments into their research work. They provide ongoing feedback to the citizens and acknowledge their work.	Researchers provide resources, advice, and assistance to support citizens further utilize CS projects, to create new research-related activities, implement trainings, or conduct own research.

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In moving from 'inform' to 'empower' citizens are increasingly involved and become deeper engaged in the citizen science project and its research. With each step citizens are offered greater participation and at the same time growing influence on the research projects and work. The REINFROCE framework for Citizen Engagement in Citizen Science can also be modified and applies for the different target groups and their specific needs and challenges. Educators have different needs and interests, than other groups, and visually impaired citizens face different challenges for developing a relationship with the research teams.

In Citizen Science the type of engagement offered in projects depends on the goals, time frame, resources, and levels of research. Citizens also may be interested only in a specific level of participation, which is not only legitimate but a basic feature in citizen science projects.

However, Table 15 above takes only the researchers needs into consideration, and therefore needs to be extended to include the engagement level of the citizens into account. After all, the engagement is always a two-way process, and it is especially needed in citizen science project to find an appropriate balance between all stakeholder groups and at each level of engagement (see Table 16)

4.3 Citizen Science Support Mechanism

The level of citizens engagement needs to be accompanied by the types of engagement activities that can be offered to facilitate a participatory engagement process. To achieve a long-lasting and impactful participatory engagement in REINFORCE citizens' needs, interests and motivations are the key factors that will determine the success of the engagement in REINFORCE Citizen Science projects. Therefore, the engagement levels as introduced in the previous sections, needs to be connected with a set of activities that creates the integrated REINFORCE experience for all interested citizens and that has the potential to retain their participation as well as to keep motivation and interest up throughout the REINFORCE project duration (and beyond).

The REINFORCE Citizen Science projects are demanding in terms of research and subject domains in frontier physics. This adds to the complex challenges of engaging a broad and inclusive group of citizens in the project. It is therefore essential, that the project (science and engagement) teams understand that they need to become also enablers and coaches for the interested citizens. Throughout the project duration, the team needs to offer support on different levels, depending on the target group and their needs. For example, educators - who have the potential to multiply participation by integrating the REINFORCE demonstrator projects in their formal and non-formal educational activities – need the support by having access to educational resources and learning pathways for their pupils and students.

The planned activities under WP8 in REINFORCE should therefore be understood as an integrated "**REINFORCE Citizen Science Support Mechanism**" that provides custom-made scaffolding to the various main citizen groups. The aim is to provide support by offering tutorials, enabling dialogue and feedback, helping citizens to perform the tasks and investigations, classifications, and analysis. To realize the full potential of citizens to contribute, collaborate, and discuss their finding and results, it is necessary to provide them with the necessary knowledge, guidance, training and support so to create the conditions for citizens to fully appreciate and take part in their new, challenging role as citizen scientists.

The 5 Levels of Engagement need therefore to be augmented with the support activities. The main types of support activities can be distinguished between:

- **Awareness Activities**: The main objective of this first type of engagement activities is to provide information and create awareness about the existence, aims and objectives of the REINFORCE Citizen Science projects. They introduce the topic and explain the need of researchers for help, the available tools, and platforms to be used. Activities should highlight the opportunities for citizens to get involved and the potential for adaptation for the specific target groups.
- **Training Activities**: (Online and offline) Training events are a central activity to ensure that citizens have the opportunity to fully participate ***as partners*** to the scientists in the REINFORCE projects. The complexity of the topics make it necessary to offer explanations, provide context and inspiring

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introduction to fundamental research in physics, so anyone – even (or especially) those that have no or little knowledge about the subjects - can understand, follow, and appreciate the research process. The training events are opportunities to introduce and explore the projects, understand the necessity of the research and its methodology, and provide the needed context.

- **Support Activities**: Direct support provides citizens with the necessary assistance to overcome problems, misunderstandings, and give answer to their immediate questions. It creates a sense of partnership in a project when direct support and feedback are given and increases their confidence and commitment to the project. The Zooniverse platform also allows a peer-to-peer support through the chat and forum function. Another element can be (live and online) demonstration activities showcasing new tasks, features, or data. Pilot days (e.g. in schools) can support teachers in the adaptation of resources and the implementation of educational scenarios in schools.
- **Community Building Activities**: Direct support is limited by time and resources; therefore, the project needs to create communities of practice (per project and/or per citizen group) that can offer additional help and support. The size of and activity within a community are good indicators of the sustained success and sustainability of the REINFORCE projects. The mechanisms to support the creation and continuation of communities are especially important for key target groups such as teachers. Ideally, the project can create a cascade effect where teachers convince and train other teachers to join the projects and the integration to schools.
- **Recognition Activities**: The importance of recognition for citizen scientists is not questioned. An efficient recognition mechanism that validates and appreciates the participation of citizens and that can distinguish and recognize their level of involvement is clearly advantageous to retain and keep users committed to the project. Some user groups may require certification to ensure a greater commitment as it can be an integral part of professional development activities (e.g. for teachers).

The overall concept and detailed breakdown of the Community Support Mechanisms activities will be drafted and published in D8.1. Nonetheless, the following section briefly introduces activities as part of the Citizen Engagement Plan.

An overview of the types of activities and their connection to the established levels of engagement offer Table 16

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Table 16 Proposed Events Per Engagement Level

Level	Inform	Consult	Involve	Collaborate	Empower
Goal	**Awareness**	**Consultation**	**Co-creation**	**Implementation**	**Utilization**
Engagement Activities (online)	Website / Social Media Newsletter Webinars Outreach activities of LRI (Online) Conference presentations	Vision-Building Workshop Survey	Demonstrations of projects Practice-Reflection Workshop Online Preparation / Training on subjects Community Building	Practice-Reflection Workshop Tutorials Training (on subject & project) Contests / Competitions Forum / Discussions Community Building Recognition (e.g. badges / social media / newsletters / publications)	Contests / Competitions Educational resources workshops Co-created Conference publications Training accreditation
Engagement Activities (offline)	Leaflets Info-days / Conference presentations Outreach activities of LRI	Vision-Building Workshop Feedback questionnaires Discussions	Summer Schools Pilot-days / Demonstrations (e.g.in schools) Practice-Reflection Workshop Preparation / Training Workshops	Practice-Reflection Workshop Training / Summer Schools Demo-activities (e.g. for sonification, schools)	Summer Schools Teachers training teachers Science Cafes Open Schooling Days Open Lab Days Co-created publications

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4.4 Proposed Engagement Activities

The following chapters briefly introduce some of the proposed events per engagement level and according to which goals are to be achieved. However, most of the activities or events are not limited to one phase only but can be organised to support other citizen engagement levels. In fact, this is an initial toolbox of ideas, and will be adapted as we progress in the project. The full support mechanisms will be described in D8.I

The events are briefly described and links to specific recommendations of the bibliographic reviews are included.

4.4.1 Information: Awareness

Recruiting needs to become an ongoing activity throughout the duration of each REINFORCE project. The goal needs to be to disseminate information, promote its opportunities and make them known through the existing communication channels and tools to reach out to the greatest number of potential participants. This work is mostly attributed to WP10 and its activities but should be understood in the larger context of an all-inclusive engagement plan.

To inform and engage the public, and to allow for engagement in citizen science, one needs to first to build awareness about the concept of citizen science, the project, its goals and objectives, the opportunities of engagement and participation, etc. and develop channels of communication between the science teams and the public. However, it should be stressed that raising awareness activities are the first important step for participatory engagement and plays a crucial role in the overall process. Posts on the website and social media sites can increase awareness for purely dissemination purposes, but they can also be an important instrument in keeping people engaged, e.g. by learning about success stories, achievements of citizen scientists, etc. The content produced under awareness, should be inspiring with the goal to encourage many people to join the process. The main tools for the Awareness phase are:

- Website / Social Media
- Newsletter Webinars
- Outreach activities of LRI
- (Online) Conference presentations
- Leaflets
- Info-days / Conference presentations

➔ Regular webinars (e.g. stream via YouTube) to present project progress to citizens keep them informed and engaged.

Webinar (Example)

Figure 5: Announcement for the REINFORCE Webinar

On 01 June 2020, REINFORCE offered its first Webinar organised by TRUST-IT to introduce the REINFORCE project to the European Research community and to the broad public of potential citizen scientists. The Webinar focused mostly on presenting the ideas of the four Citizen Science projects that are currently being developed. With this workshop, REINFORCE increased awareness about its activities of cutting-edge citizen science projects on frontier Physics research, and it was the first

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step to invite citizen to join the project and to make a genuine and valued contribution to managing the data avalanche.

The webinar was hosted by the Project Coordinator Prof. Stavros Katsanevas, and introduced the themes and context for the four REINFORCE Citizen Science Projects. While there was a chance to ask questions, the webinar did not serve to gather specific feedback. Further thematic webinars are planned to take place throughout the project duration. For more information and the recording please see here: https://reinforceeu.eu/events/webinars/bridging-gap-between-science-and-society-through-citizen-science.

4.4.2 Consultation

Starting from the Consultation level, all REINFORCE activities aim to start a reflective process that take into consideration the ideas and visions of the science teams, but aim to understand the citizens expectations, concerns, wishes, etc. facilitation a live and creative dialogue and discussion process. To foster dialogue, mutual understanding and exchange of views, the activities should be repeated and adapted for each of the various target groups. From the consultation level on, the participatory engagement activities aim to overcome a distancing relation between science and the rest of the society. They are meant to empower citizens, but at the same time seek to change the involved scientific community, reshaping the relationship with citizens and making them more inclusive. They reconnect science and society in the long term by creating shared common goals.

REINFORCE introduces several highly innovative citizen science projects in challenging domains and working with Large Research Infrastructures which up until now have not been extensively involved in citizen science. Scientists of LRIs are not used to building projects aimed to gather contributions or analysis from citizens or having to interact directly with them. However, the most efficient way to design citizen science projects is to co-create and co-design their design, structure, and activities, though direct interactions and feedback form the future citizen scientists. More specifically, only by creating conditions that are like the end projects, citizens can offer concrete feedback on the use and overall experience.

In the end, citizens are best placed to identify the way the research activities and results can become meaningful for them. It is one of the key goals of REINFORCE to involve and empower citizens to utilize the research for their own purposes, generating a greater appreciation of science and the work in Large Research Infrastructures, and promote a deeper knowledge about their priorities. REINFORCE's intention is to involve the citizens in more activities, and to make participants become part and contribute also towards the design of projects, facilitating a dialogue between the research teams and non-expert citizens that could challenge, improve or extend the initial ideas and plans. Ideally, the REINFORCE project are being co-created and activities and tasks are being adjusted to the needs or aspirations of citizens.

The main types of activities and event that support the goal for this level are which ideally should be applied within the same event:

- Survey (see chapter 2.5)
- Vision-Building Workshop, including
  - (online) Feedback Sessions
  - (Structured) Discussion

Figure 6: Consultation Process and Requirements Elicitation

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4.3.2.1 Vision-Building Workshops

The Vision-Building Workshops aim to entice higher levels of engagement than the simple dissemination efforts and events. While they are also important tools for awareness, they seek to present a new common vision, and should offer to the participants a first experience related to what to expect from the project and what it can offer to the future citizen scientist. At the end, participants should have understood the vision and ideally experienced a part of it, so to appreciate its intended goals and have a clear view of the opportunities that it offers to them.

At the same time, these workshops also serve to promote and extract shared objectives between the science teams and the volunteers. The workshops offer far more practical value than the desk research review to understand the user's motivations and interests. Vison-building workshops should include interactive events, to increase reflexivity and thereby the level of validity of the proposed ideas and tasks. Ideally, they can act as a "reality check" for the project teams as it provides often time the first instance where they interact and face the citizens they hope to work with.

Especially at the beginning of the project, user should have the chance to learn about the citizen science project design, test pilot some of the activities and learn or propose instances where the project or part of its activities can be integrated to their personal or professional environment, e.g. links to the school curriculum for teachers. The research teams are advised to reach out to various user groups of diverse backgrounds, discipline areas, social environments to effectively understand their needs. Successful events should convince participants to join REINFORCE, provide ongoing feedback and to continuously co-design or create the research projects. Volunteers move from a stage of awareness to a stage of interest, and to decide to invest in their own development moving towards the training activities.

In July 2020, REINFORCE organised two Vision-Building Workshops. One was open to the general public, while the second one was specifically design for educators in school education. Below is brief overview of the events, their agenda and feedback collection methods.

➔ Such events have been a clear recommendation to identify citizen needs and priorities.

➔ Visionary workshops can be especially useful to identify their needs, goals and main motivations for marginalized groups

➔ Senior participants should be invited to an Intergenerational setting with younger people as coaches in school-like settings

Example: Vision-Building Workshop (General Public), 21 July 2020

Citizen Science creates numerous opportunities for all citizens – independent of their location, gender, or education - to be involved in ground-breaking fundamental research. Through citizen science activities, everyone can contribute to the development of new knowledge. Increasingly, scientists from Large Research Infrastructures and Frontier Physics experiments are starting to share their data and ask for citizens to support the optimization of their detectors to enhance discoveries potential.

But how can citizens support their work?

The workshop was broadcasted on Zoom on the 21st of July 2020 from 10:00 AM to 12:30 AM CEST, and showcased the intended citizen science projects in frontier physics, presented by experts from infrastructures such as CERN, VIRGO/EGO, or KM3NeT. They introduced their ideas and engaged with participants to better understand their interest, motivations and ideas to get involved and contribute in citizen science.

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Figure 7: Announcement Of REINFORCE Vision-Building Workshop

Target group: General Public / Educators

Attendees: 72 / 47

Date: 21/22 July 2020

Location: Online

More information on the REINFORCE website.

Goals:

1) Introduce participants on the key aspects of citizen engagement in (citizen) science
2) Explain the project's vision / showcase examples of how citizen can contribute to large research infrastructures
3) Present hands-on experiences of how citizens can contribute to the work of Large Research Infrastructures
4) Build interest in participating in REINFORCE demonstrator projects
5) Understand their interest and motivation to participate in REINFORCE citizen science projects.

Table 17 Agenda of Vision-Building WOrkshop

Time	Topic
10:00 – 10:05	**Welcome / Introduction to the Agenda**
10:05 – 10:20	**Interactive Session 1:** Citizen Science
10:20 – 10:40	**Do Large Research Infrastructures need citizens to contribute to their work?** The example of **VIRGO** and Gravitational Waves
10:40 – 10:50	**Interactive Session 2:** 'Science'
10:50 – 11:10	Demonstration: **Gravity Spy on Zooniverse**
11:10 – 11:30	**Hands-on Session**: Contributing to Gravity Spy on Zooniverse
11:30 – 11:45	**Interactive Session 3:** Citizen Science on Zooniverse
11:45 – 12:05	**Can citizens help scientists to open a new window on our Universe?** The example of Neutrino Telescope and **KM3NeT**
12:05 – 12:25	**Outlook**: **How can you participate in REINFORCE?** The Citizen Science Projects in REINFORCE
12:25 – 12:30	**Interactive Session 4: Getting Involved (and staying involved)** **Ending of Visionary Workshop**

Collection of feedback from attendees

This online vision-building workshop provides a good chance to apply and test the concept of engagement and interaction. The event was widely promoted and attracted overall 72 participants that followed the presentations. The workshop was build to include ample time for interaction, and to facilitate this process we chose to use an online survey tool: Mentimeter. In Figure 9+10 are presented some of the most significant outcomes.

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Familiarity with Large Research Infrastructures

Before the workshop introduced the project and the work or intended aims of the REINFORCE citizen science projects, attendees were asked if they could confidently explain to a friend the work of the LRI that are part of the REINFORCE. As CERN seems to be known better than VIRGO and especially KM3NET it seems that the demonstrator CS project connected with CERN could be a good starting point to involve citizens. In any case, it is a clear indication that for VIRGO and KM3NET more explanation about their work need to be offered.

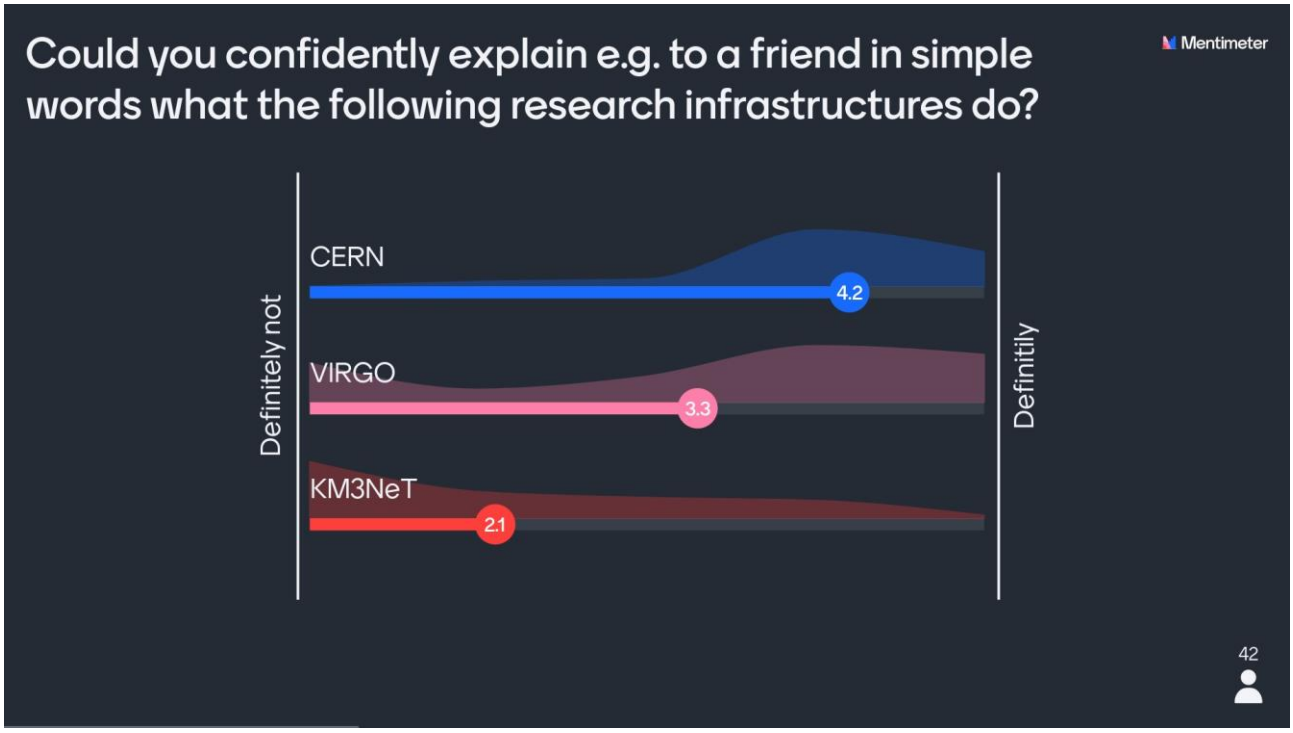

Figure 8: Familiarity with LRIs

Familiarity with Citizen Science

About 66% of attendees that participated in the Mentimeter activity, responded that they are familiar with the concept of citizen science, which is in line with the expectations and the online survey results. When prompted to provide up to three words that they connect with that concept **innovation**, **participation**, **contribution** and **collaboration** were named the most, which provides a good overlap with the consortium's understanding.

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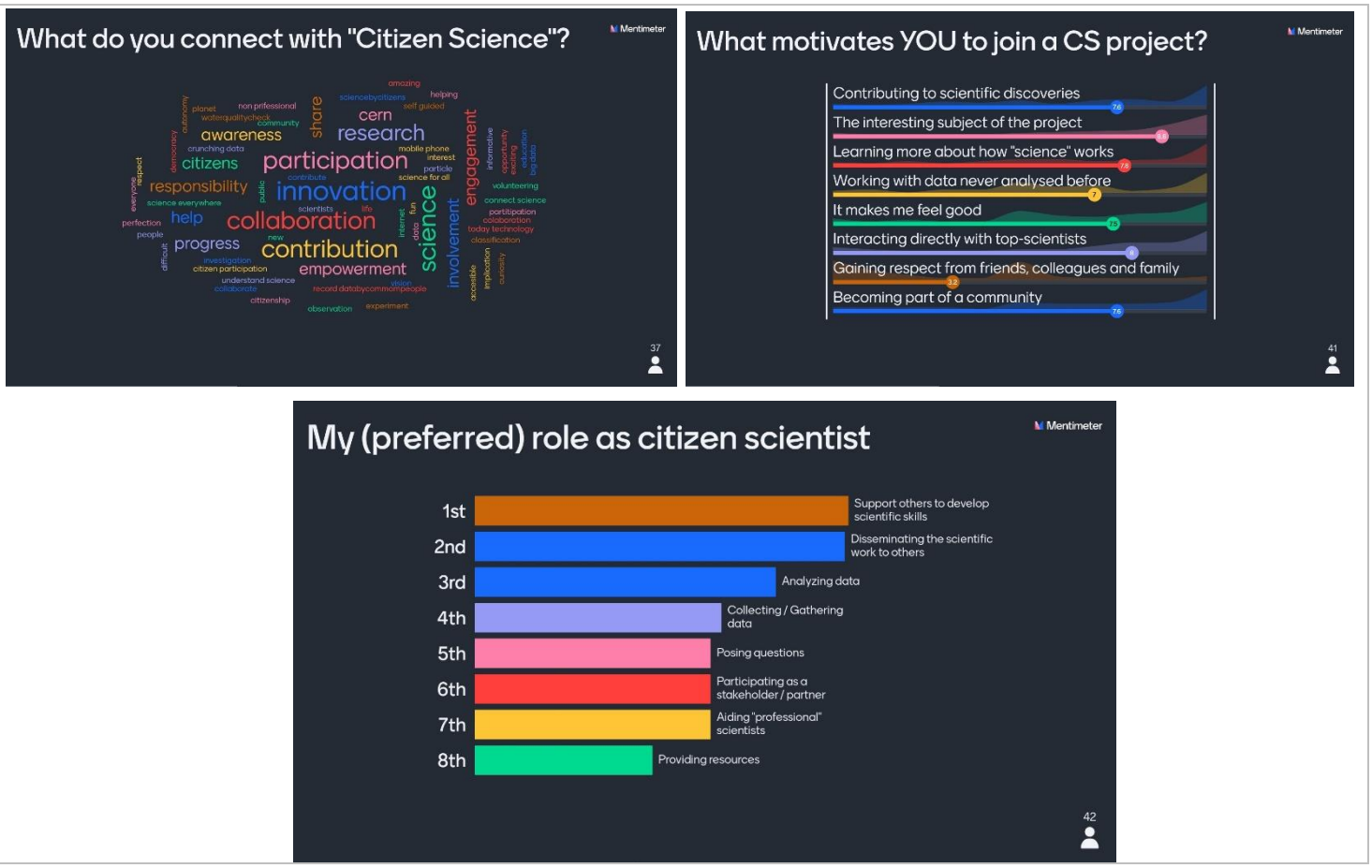

Figure 9: Familiarity with Citizen Science

More striking are the observations regarding their motivations and the preferred role in a citizen science project. The interest of a CS project seems to be one of the main motivational factors along with the chance to interact with top scientists in their field and understanding the process of scientific research. However, among the attendees there was more interest in participating in a CS project to support other to learn scientific skills or disseminate the work to others, than to aid scientists in their filed of work.

At the end of the workshop attendees were asked to allocate points to indicate their preference for each of the REINFORCE demonstrator projects. Gravitational Wave Noise Hunting was by far the preferred choice, but it was also the project that received the most attention during the workshop.

Figure 10: Preference for REINFORCE CS project

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4.4.1 Involvement: Co-creation

Citizen science projects ideally form a partnership between professional scientists and volunteers in scientific research. The projects vary in the degree to which people participate, and participation at higher levels of engagement integrates characteristics of co-creation. The meaning of co-creation in Citizen Science is relatively loose in comparison with other disciplines. The terms "co-created," "co-designed," and "co-constructed" for Citizen Science projects are frequently interchanged[4]. But the process can be an important part to add relevance, increase impacts, contribute to knowledge production, and help participants improve their own skills, e.g. on education.

To help interested participants become engaged volunteers and in fact partners or stakeholders in the scientific research, participatory engagement activities are the main drivers. The Vision-Building Workshops are the first step, but it is important to keep the direct feedback channels open and be able to react to shifting needs of the users. Participatory engagement activities could comprise of:

- Practice-Reflection Workshop
- Preparation / Training
    - Online training
    - Training Workshops
    - Summer Schools

Practice Reflection Workshops

Practice Reflection Workshops any type of activities where user, volunteers and participants of the projects are being asked to reflect on their experience and provide useful insights on how the project could be improved or the experience made more impactful. These activities are crucial points to monitor and anticipate necessary changes to the process, project design, key actions to ensure the success of the REINFORCE initiatives. For the participants it is a good chance to enhance their knowledge and feel more competent and confident to take part in the citizen science projects. Furthermore, volunteers feel more involved to the project and becoming part of the design process increases the sense of ownership. This process provides reflection and discussion opportunities, and is a key aspect of the creating REINFORCE communities for each demonstrator project.

➔ Regular practice reflection workshops are an important recommendation to ensure that the project activities take motivation, feedback and interest of all groups of citizens into account.

➔ The attendance of high-profile scientists that interact directly with citizens is recommended

(Online) Training Workshops

REINFROCE offers projects in subject domains which pose challenges not only for the design in implementation but also for participants in terms of scientific, educational and engagement goals. Many challenges are expected as participants will be involved in tasks and practices that they were not trained to perform. For example, it is to be expected that most participants are not aware of neutrino astronomy itself, or the associated scientific terms, and may not have the knowledge required to carry out accurate data analysis. It is therefore needed to develop and provide training sessions that support the volunteers to feel comfortable to undertake the tasks while ensuring that all desired outcomes are being satisfactorily accomplished for the science teams as well. Providing trainings will help to obtain the required scientific outcomes while at the same time improving participants' scientific literacy and knowledge. In addition, they

[4] Skarlatidou A, Suškevičs M, Göbel C, Prūse B, Tauginienė L, Mascarenhas A, et al.. The Value of Stakeholder Mapping to Enhance Co-Creation in Citizen Science Initiatives. Citizen Science: Theory and Practice. 2019;4(1):24. DOI: http://doi.org/10.5334/cstp.226

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open another communication channel for clarification, answering questions, exchange of ideas and success stories. These events can take place on site whenever possible or online.

➔ Key recommendation: Organization citizen training workshops

➔ Training events are good opportunities to run usability testing for different types of users and adapt their feedback to the project design

Hands-on experience / Demonstrations of CS projects

The online vision-building workshop on 21/22 July 2020 have confirmed that thee is a high demand for hands-on sessions and experience. Such demonstrations provide a good opportunity to have participants experience the projects, try out the expected task while having the chance to ask for clarifications on the spot. Each event should ideally incorporate time for participants to log on to the Zooniverse platform, discover the project and test its tasks and support functionalities.

4.4.2 Collaboration: Implementation

The implementation of a Citizen Science project is more than managing the participation of volunteers and needs to continue the dialogue established in the previous phases, needs to value the contribution of the participants, ensure consistency and reliability of the work and the scientific goals. Projects should always acknowledge and recognise contributions of volunteers and their roles in project outcomes. Where appropriate, badges, awards, or other type of recognition events can help. If Citizen scientists are to become collaborators and partners in the projects, they also need to receive and give regular updates and feedback, as a critical way of sharing progress. Projects need offer opportunities to help volunteers understand not just what is happening, but also how the results are applied to the research, and the role of the citizen scientist's contribution. The process of interaction between science teams and citizen scientists to mutually understand the interests, motivations and goals continues to be even more crucial now. Events to faciliate that process are:

- Practice-Reflection Workshop
- Tutorials / Training (on subject & project) – as part of the support mechanism
- Recognition (e.g. badges / social media / newsletters / publications)
- Summer Schools
- Demo-activities (e.g. for sonification, schools)

Practice Reflection Workshops

Especially while the volunteers run and implement the REINFORCE projects Practice Reflection Workshops can provide great support for both sides. Their intent is to collect the input from the practitioners and their experience in e.g. using the Zooniverse platform, integrating Citizen Science in school education, etc. These workshops will be organized online but also in site in the participating countries extending further the interaction process of REINFORCE. The volunteers and other users of the demonstrator projects have thus the chance to reflect on their experience and provide useful insights on how the project / platform needs to be adapted or enhance, or how pedagogical approaches can be better integrated. These activities are crucial points to monitor and anticipate necessary changes to the process, key actions to ensure the success of the project. By providing reflection and discussion opportunities, by giving feedback to the participants on the results of their suggestions and reflections is a key aspect of the sustainability of the REINFORCE projects and support community building.

Summer Schools / Extended Training

Summer schools provide a good opportunity to bring together the science teams as well as pedagogical, technical and assessment partners and bring them in direct contact with a key target group in REINFORCE: teachers. The 5-6-day training events can facilitate the use and implementation of the projects in a broader

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context, such as school education. It also provides a framework to collect immediate feedback on the design of the projects, the support resources and educational scenarios and the technical platform. It can also serve to build rapport between the teachers and the project team, introduce and discuss the overall approach and address all identified challenges and concerns of the teachers that will implement the REINFORCE approach in their classroom.

➔ Offering such professional development opportunities that allow to discuss with them REINFORCE, showcase the science case and educational merits, to present them with generic educational activities is a key recommendation

Recognition & Demonstrations

Recognition and/or **certification** of participation in the project or in training, can be used as an important recognition mechanism that endorses the investment of volunteers in REINFORCE demonstrator projects. Certified training courses are part of the efforts being implemented in some of the participant countries. These training courses are hubs that act as an important ingredient for the enrichment of their competence profile. Certificates are ready to be distributed and are designed as a recognition mechanism for the various types of engagement of the teachers as described in this document. They encompass the recognition of the different stakeholders from the school community starting with the recognition of the school, going to the teachers and the students.

➔ Recognition of (individual) accomplishments can be a very effective tool to sustain citizens engagement

➔ Users that have excelled should be invited to act as “ambassadors”, role models or mentors

Digital badges will also be used as an instrument to motivate the participation of citizen scientists. This strategy still needs to be designed but will follow as close as possible the Open Badge systems that are now quite popular.

➔ Offering badges or other incentives

Demo activities are events where the project partners are demonstrating the projects and the type of contributions expected. This is especially helpful in schools, as part of bringing students in direct contact with the scientists. This is a very effective tool for community building as it supports the teachers, engages students, and involve other members of the school community.

➔ Demonstrations / Pilots of activities e.g. in the classroom is a key recommendation, as it establishes opportunities of cooperation between educators and scientists running the projects.

4.4.3 Empowerment: Goal Utilization

Increasing the public’s understanding and support for science is not the main priority for many citizen science projects, yet for REINFORCE it is an important goal to empower its citizen scientists. Empowerment in REINFORCE entails various aspects, such as science education for people with various degrees of scientific literacy, inclusion of marginalised groups and impaired citizens, etc. However, by involving all citizens, and in specific teachers and students, in authentic research projects, rather than “school science,” REINFORCE aims to increase understanding of the research process.

Activities to support this level of engagement will be supported not only by events, but also by specialized citizen education and empowerment activities with the corresponding educational resources to address disadvantaged groups, and interactions of arts with frontier citizen science. REINFORCE will empower e.g. teachers to utilize and bring frontier citizen science in the classroom and investigate the potential it has, to introduce Nobel Prize Physics beyond the school curricula. In the end, involvement in REINFORCE should ideally increase the impact in high school and university students’ career motivation, science motivation, enthusiasm about science and mastery of science content knowledge. REINFORCE hopes that active participation of volunteer in the scientific process will lead to personal empowerment.

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The educational resources to support this process will be developed in WP8, and the corresponding activities that support the empowerment process include the following type of event, some of which are further described below:

- Science Cafes
- Open Schooling Events
- Laboratory Open Days
- Contests / Competitions
- Educational resources workshops (to be defined in D8.1)
- Summer Schools

Science Café's:

Science Café's across the countries will be initiated and serve as informal meetings between citizens and REINFORCE scientists, in which they will be able to present their work, to discuss further, to exchange ideas, concerns and practices. The science café's will conduct regular meetings throughout of the project. The science cafes can take place online to reach a global audience.

➔ Regular face to face meetings such as science cafes are especially appreciated by elderly people who prefer in-situ discussions.

Open Schooling Events

REINFORCE will forge strong connections with secondary and tertiary education. Teachers will be trained in specialized citizen training activities and will implement the project's demonstrators with their students in formal and informal learning activities in schools. Schools will be supported to organize Open Schooling events where they will open the school doors to local society, will present their students' work. These events will include invited talks and workshops from REINFORCE engaged citizens as well as scientists.

Laboratory Open Days

Large Research Infrastructures participating in the proposed project will organize a series of Laboratory Open Days throughout which citizens will be able to be guided in the research infrastructures themselves, discuss with scientists in the place of their work, participate in argumentations and hands-on workshops. Furthermore, citizens will be able to create posters of their work and present them to other citizens and researchers. At least one Open Day will be organized per research infrastructure participating in REINFORCE.

➔ Such events are especially impactful to engage students. "A (virtual) visit to a research institute" / "The scientist comes to the school" / "An exhibition for students" / "A REINFORCE project day".

Contests / Competitions

Contest or competitions can be interesting activities not only to increase the participation in citizen science project, but to support the integration of the activities in a broader context, such as education. Challenges could cover the production of educational resources, or ideas to address gender implications. It offers also chances to engage citizens with impairments by asking them to take part in a competition specifically designed for them.

➔ Informal / non-formal education events, e.g. competitions, classification marathons, year-long projects etc. are a key recommendation

➔ Empower citizens to organize their own event, e.g. let teachers train their peers

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5. Conclusion and Outlook

This engagement plan lays the foundation for the REINFROCE project to support its mission of co-creating inclusive citizen science opportunities with Large Research Infrastructures together with the citizens. It should not be, however, considered a final document. Instead, the plan and framework are dynamic and need to be monitored and updated. It is the start of a journey over the coming months and years, presenting initial ideas for activities and action to be organised in preparation and during the implementation of citizen science activities of REINFORCE. The various opportunities for interaction with the target groups will help us adapt this dynamic mechanism throughout the next 2 ½ years, and we hope that we can evaluate its effectiveness, highlight its impact and promote this methodology at the end of the project so it can inform and support other citizen science projects in the future.

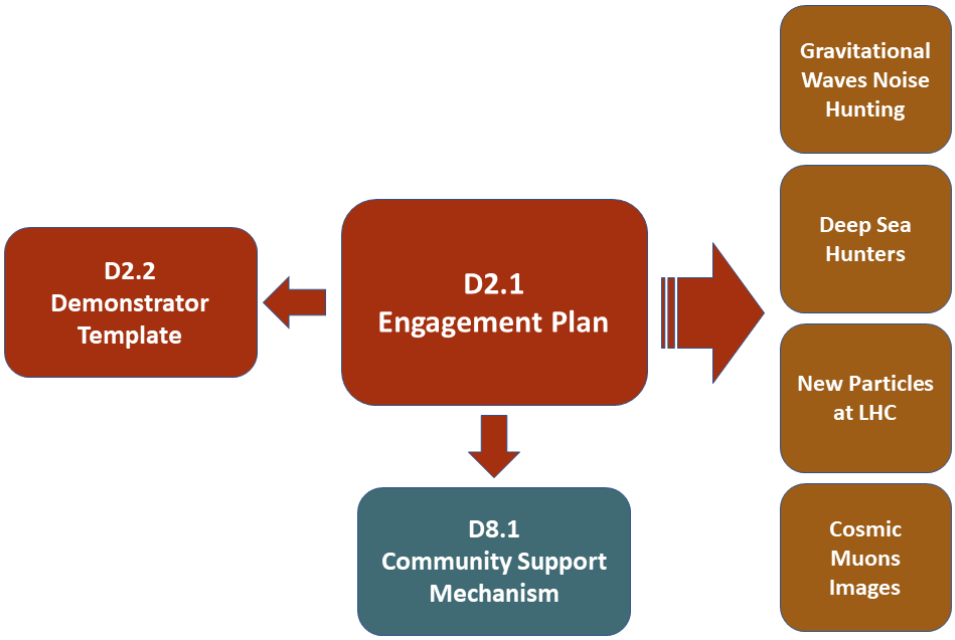

Figure 11: Central Role of D2.1 in REINFORCE

The work and analysis done in preparation for this deliverable has already been shared and discussed with the science teams of the REINFORCE demonstrator projects, but also with the team of Zooniverse to support the design of the demonstrator template of D2.2. The recommendations of the bibliographic review have been discussed with the demonstrator partners to reflect on their project design.

Overall, the bibliographic study and the first analysis of the sample of the online survey informed the engagement framework with fresh ideas, and provided some hints on where more information and training is needed (e.g. awareness and training events should be more focused on the demanding field of high energy messenger astronomy). It demonstrated a high interest in working with the LRSs in all areas.

The next steps need to focus on continuing the process of widening the outreach to broader target groups in REINFORCE, increasing the level of engagement of involved citizens, adapting the design of the Demonstrator projects based on the feedback of the citizens, and prepare the Community Support Mechanism of WP8 that will prepare the necessary resources, organise training and empowerment activities. Furthermore, it is important to support the science teams to develop their project design by bringing them in contact with the potential users, so that their motivations, perceptions, and interest are being taken into account.

The Engagement Plan and Framework of D2.1 together with the Community Support Mechanism not only aim to recruit volunteer citizens to participate in REINFORCE projects, they also seek to minimize the effects

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of losing momentum after the initial rise, and to even increase and maintain a higher participation over a longer period of time. Therefore, REINFORCE engagement activities will need implement simultaneously several activities:

- Constantly attract new user to join the projects throughout their duration, to fil in gaps left by those people leaving or stopping their involvement
- Continuously increase the size of the citizens' groups to balance the unequal distribution of effort and to achieve a more inclusive volunteer group
- Offer different level of engagement options so citizen can choose their type of involvement or the difficulty of the selected tasks
- Organise online (and if possible, in situ) workshops to provide information, training and communicate the options for giving feedback that will help improve the projects and offered support
- Create inclusive resources to for support, advice, and online tutorials to all citizen groups so they will become more confident and engaged in frontier physics
- Provide additional; resources for specific groups (e.g. for school education) that invite the integration of REINFORCE projects to their professional activities (i.e. formal education), and thus multiply participation by involving students and the wider school community.
- Enable direct interaction between volunteers and citizens with the scientists in each demonstrator project
- Build scaffolding, create levels of advancement, both within projects and between projects: for example, create involvement / learning pathways with novice, intermediate, expert badges etc.
- Be prepared to offer direct feedback through Zooniverse tools (e.g. "Talk") and provide thus additional recognition to active, interested citizens
- Organise engaging activities such as contest or competitions to entice more involvement
- Create a REINFORCE communities of practice around the projects and connect them so that more experienced citizen scientists can support newcomers to understand their tasks, answer questions and offer support
- Develop a platform where certain user groups can exchange their experience and ideas to support community development.

Most of the above issues will inform, address and be reflected in the various activities of WP8. This document set the fundament for the development of the Community support mechanism in WP8 (D8.1).

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ANNEX

Initial Analysis of Online Survey

Survey Report

This survey aimed to identify the potential target groups of REINFORCE, explore their characteristics and investigate: a. their interest to contribute in REINFORCE; b. their primary motivations in order to participate in REINFORCE projects, following the outcomes of the bibliographic study; c. the factors that can affect their sustained participation in the REINFORCE citizen science projects. This survey is an ongoing process and the results reported here can be considered preliminary, yet enlightening.

Sample Size

The sample consists of 263 citizens (37.1% male; 62.9% female) with the following distribution of ages:

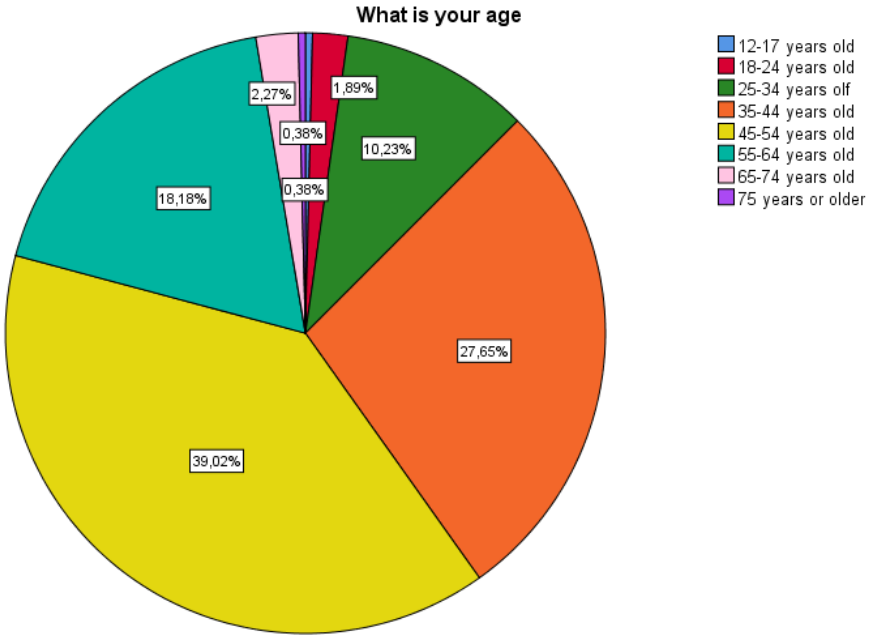

Figure a. Age distribution of survey respondents

34.9% of the participants come from Greece, 10.8% come from Romania, 8.2% come from Portugal, 7.1% come from Italy and 7.1% from Spain, while the rest are on average equally distributed across 31 countries.

The majority of the participating citizens have a strong educational background, having acquired at least a Bachelor's degree:

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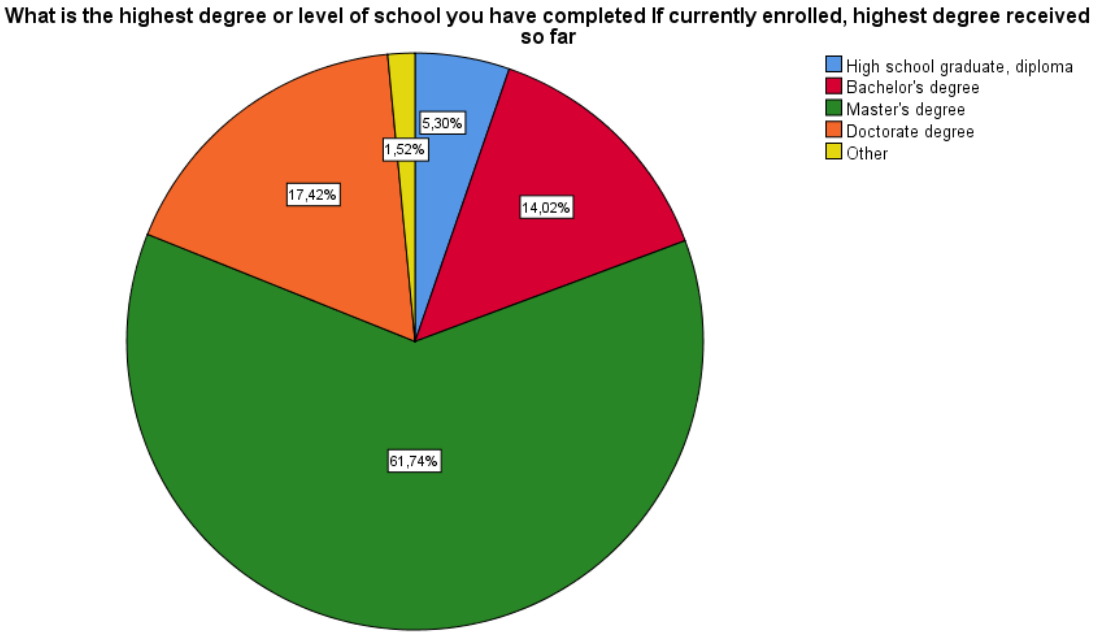

Figure b. Highest formal education degree of survey respondents

Out of these participants 86% are currently employed. 65.9% have been or currently work in a research center, university or academic research. 36,4% state that their profession is related to Natural Science and 31.8% are currently teachers in primary and secondary school.

Participants' awareness of citizen science

A series of questions were asked to participants in order to gauge their awareness and prior experience with citizen science. The majority of the participants (57%) are aware of citizen science. 28.5% of the participants have participated before in a citizen science project and 55% of these have participated in projects related to Physics/Astronomy.

Participants' disposition towards science

The survey participants were asked to state if they see themselves as "very into science", if they "quite like science", if they are "not that into science" and if they "really dislike science". More than 90% of the participants answered that they are "very into science" or "quite like science".

Regarding the societal benefits of science, more than 75% of the participants agree or strongly agree that science has a positive impact to society, while only 6% disagree or strongly disagree that science has benefitted them personally.

General knowledge about science

In order to assess the participant citizens' general knowledge about science, a series of questions were asked them with the following options as answers: true, false, not sure.

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Table A: Questions to assess participants' general knowledge about science

	True (%)	False (%)	Not Sure (%)
Spacetime can ripple	63.88	5.32	30.80
Astrology is an important part of science	28.52	66.92	4.56
Electrons are smaller than atoms	87.45	8.75	3.80
Humans, as we know them today, evolved from earlier species of animals	79.47	10.27	10.27
Light travels faster than sound	94.68	3.80	1.52
Antibiotics kill viruses as well as bacteria	13.69	73.38	12.93
It's possible to detect cosmic particles that are passing through the earth	76.81	3.42	19.77
Cosmic radiation can help visualize the inside of huge solid objects, such as mountains	43.35	13.69	42.97
All radioactivity is manmade	3.04	86.69	10.27
The continents have been moving apart for millions of years	93.16	3.80	3.04

The participants' answers are considered satisfactory taking into account their educational background, with the exception of the 10.27% "false" answer regarding the evolution of species and the 28.52% "true" answer to the question : "Astrology is an important part of science". These two questions are considered as indicators through which the overall science literacy of participants could be evaluated. Questions such as "Spacetime can ripple" or "cosmic radiation can help visualize the inside of solid objects, such as mountains" have a high percentage of participants who are not "sure", something expected taking into account the advanced character of these topics. With the increase of statistics of the survey, safer results will be able to be obtained.

Self- Reported familiarity with terms of scientific vocabulary relevant to REINFORCE

Going beyond general science questions, the REINFORCE Citizen Survey includes a list of vocabulary items relevant to the subject content of the REINFORCE citizen science demonstrators. The vocabulary items address Physics concepts of varying sophistication, concepts about the detection principle utilized in the respective research infrastructures as well as observables relevant to the REINFORCE demonstrators. Participants were asked to report the familiarity they have with these terms through a 1-4 Likert scale (1: Not familiar at all; 4: Very familiar).

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Table B: Vocabulary Items relevant to the REINFORCE Demonstrators and respondents' familiarity with them (1: Not familiar at all; 4: Very familiar).

	Vocabulary Item	**Main Reference Demonstrator**
1	Gravitational Waves	Gravitational Wave Noise Hunting
2	Interferometer	Gravitational Wave Noise Hunting
3	Glitch	Gravitational Wave Noise Hunting
4	Neutrino	Deep Sea Hunters
5	Neutrino telescope	Deep Sea Hunters
6	Bioluminescence	Deep Sea Hunters
7	Particle collision	Search for New Particles at the LHC
8	Particle collider	Search for New Particles at the LHC
9	Particle detector	Search for New Particles at the LHC
10	Proton	Search for New Particles at the LHC
11	Vertex	Search for New Particles at the LHC
12	Cosmic Rays	Cosmic Muons Images
13	Muography	Cosmic Muons Images
14	Absorption	Cosmic Muons Images
15	Elementary particle	Cosmic Muons Images , Search for New Particles at the LHC, Deep Sea Hunters
16	Muon	Cosmic Muons Images , Search for New Particles at the LHC, Deep Sea Hunters
17	Signal and noise	All
18	Spectrogram	Gravitational Wave Noise Hunting; All (after introduction of sonification)
19	Rate	Deep Sea Hunters, Cosmic Muons Images
20	Waveform	Deep Sea Hunters, Gravitational Wave Noise Hunting; All (after introduction of sonification)
21	Scattering	Search for New Particles at the LHC, Cosmic Muons Images
22	Electric charge	All
23	Radioactivity	Deep Sea Hunters, Search for New Particles at the LHC, Cosmic Muons Images

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The following chart summarizes the results of the respondents' familiarity to the vocabulary items.

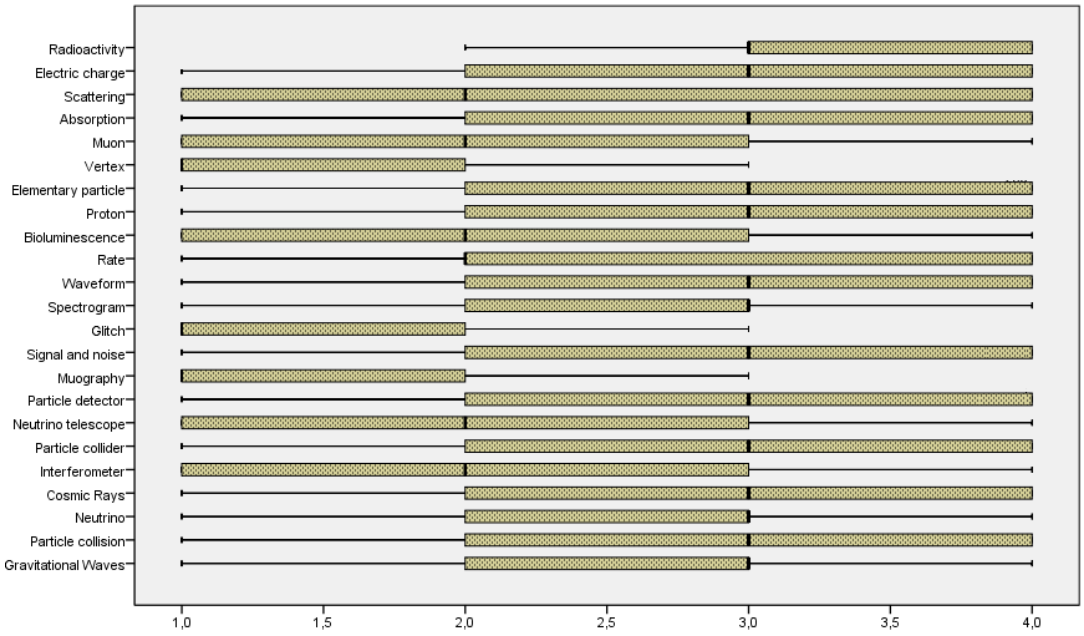

Figure c. Citizens' familiarity per vocabulary item

We observe that the vocabulary items: "Vertex", "muon", "bioluminescence", "glitch", "muography", "neutrino telescope" and "interferometer" have the lowest scores in terms of citizens' familiarity with them. The citizens' familiarity per demonstrator specific vocabulary items can be found below.

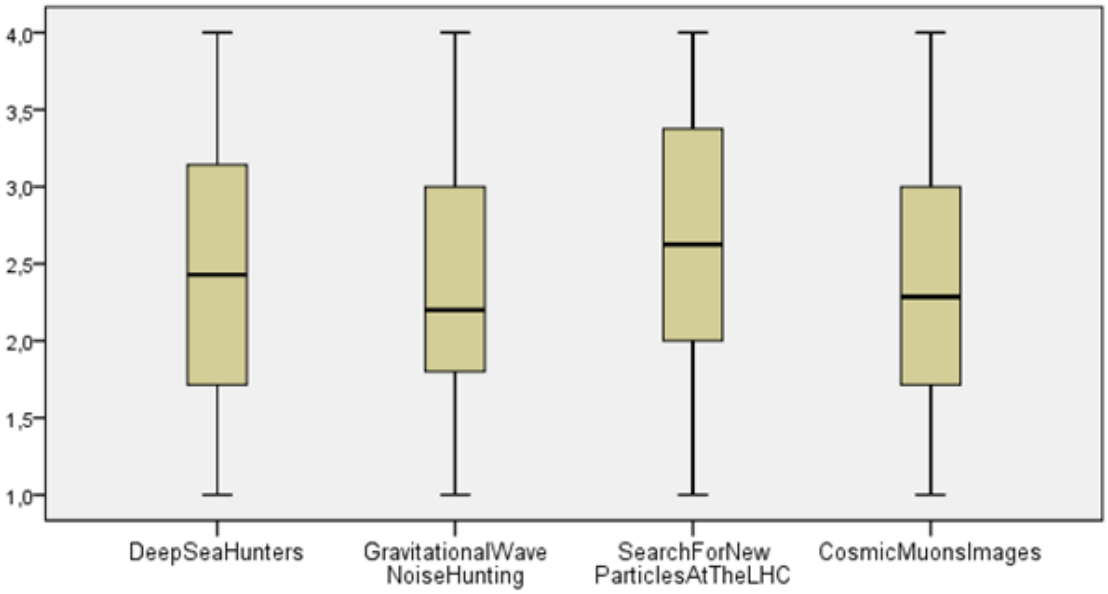

Figure d. Citizens' vocabulary familiarity per REINFORCE demonstrator

We observe that the vocabulary familiarity per demonstrator is above average with the one related to CERN displaying a higher trend than the others. With the increase of statistics of the survey, safer results will be able to be obtained. The following question asks participating citizens to state how confident they are to explain to a friend what the three research infrastructures, that the project's demonstrators correspond to, do.

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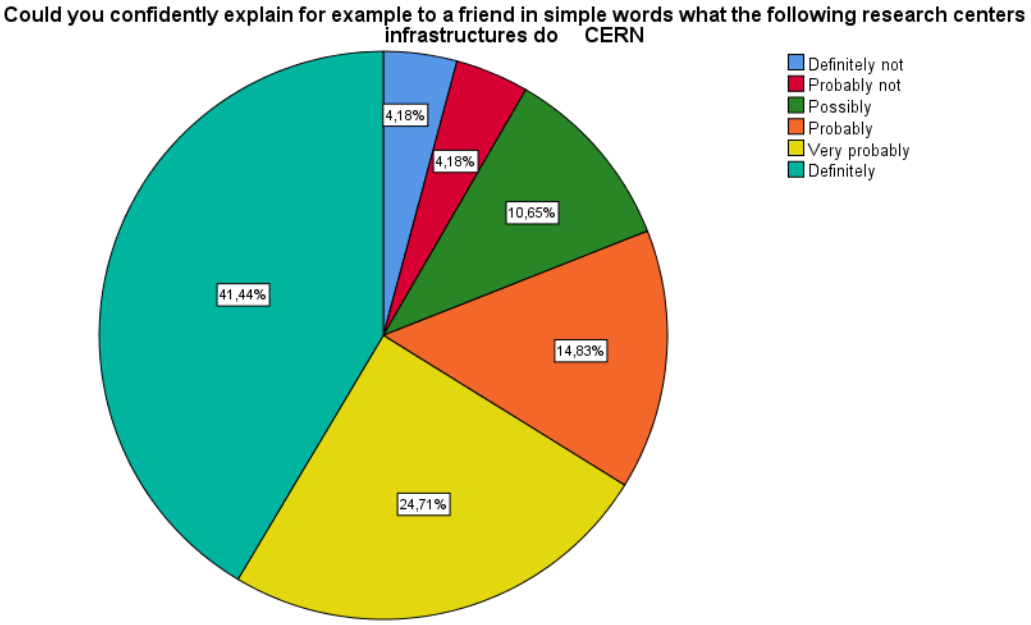

Figure e. Citizens' confidence in explaining to a friend what CERN (Relevant REINFORCE Demonstrator: Search for New Particles at the LHC) does

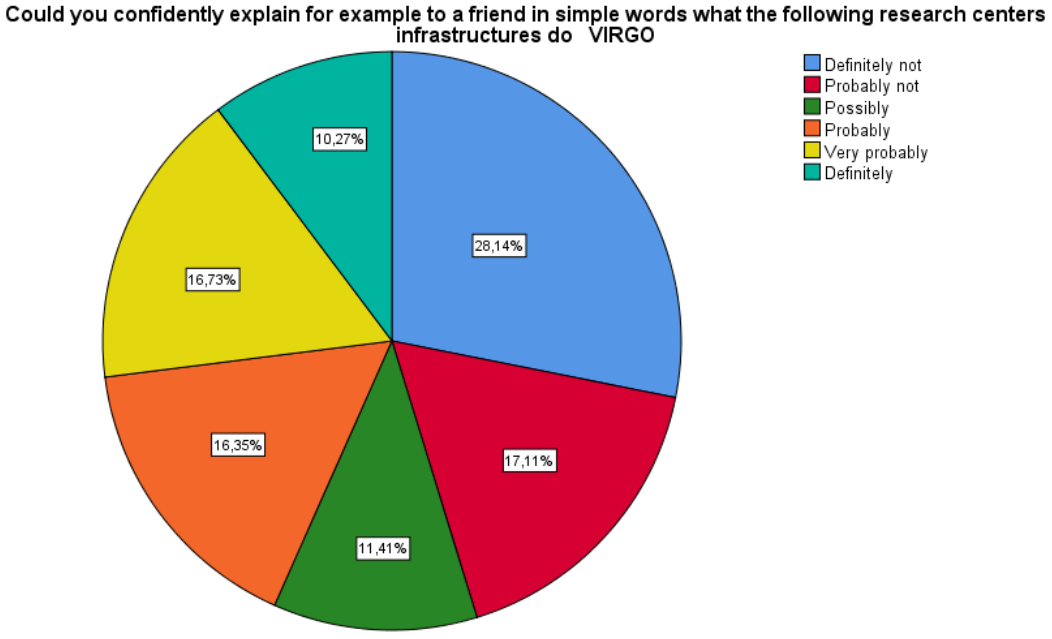

Figure f. Citizens' confidence in explaining to a friend what VIRGO (Relevant REINFORCE Demonstrator: Gravitational Wave Noise Hunting) does

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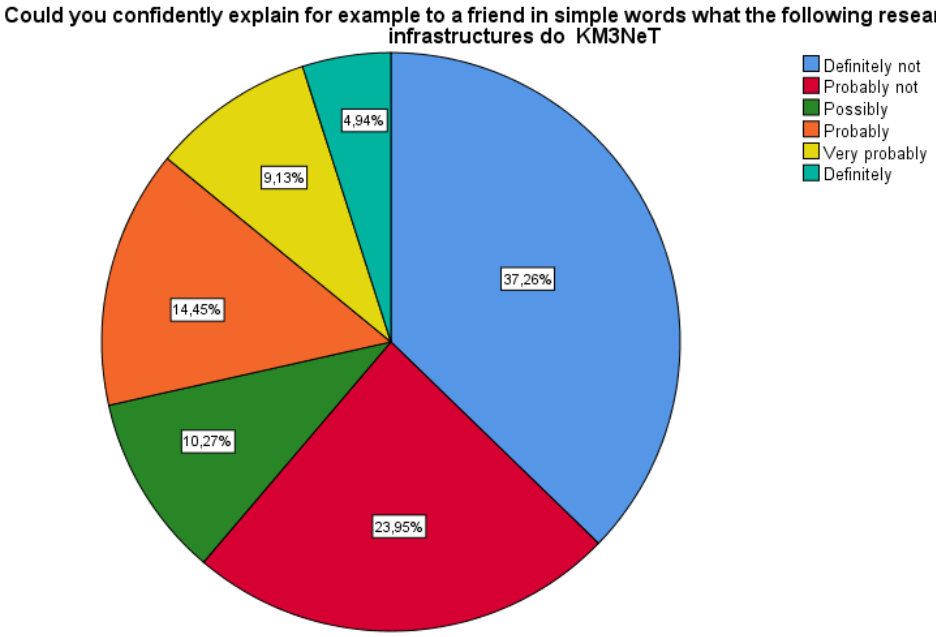

Figure g. Citizens' confidence in explaining to a friend what KM3NeT (Relevant REINFORCE Demonstrator: Deep Sea Hunters) does

The findings stated above indicate that while more than 65% of the respondents feel confident to explain what CERN does to a friend, only 27% feel confident to explain about VIRGO and 13% about KM3NeT respectively. These findings, combined with the results of vocabulary familiarity per demonstrator, indicate that the majority of the topics introduced by REINFORCE are quite novel and might be difficult to understand to the respondents. In this framework, REINFORCE needs to focus specifically on the educational aspects of its demonstrators, offering high quality educational resources and organizing participatory activities that will support citizens' training in these issues.

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The main aim of large research infrastructures

This section of the citizens' survey investigates the respondents' perceptions on the mission of Large Research Infrastructures in Physics such as VIRGO, KM3NeT or CERN.

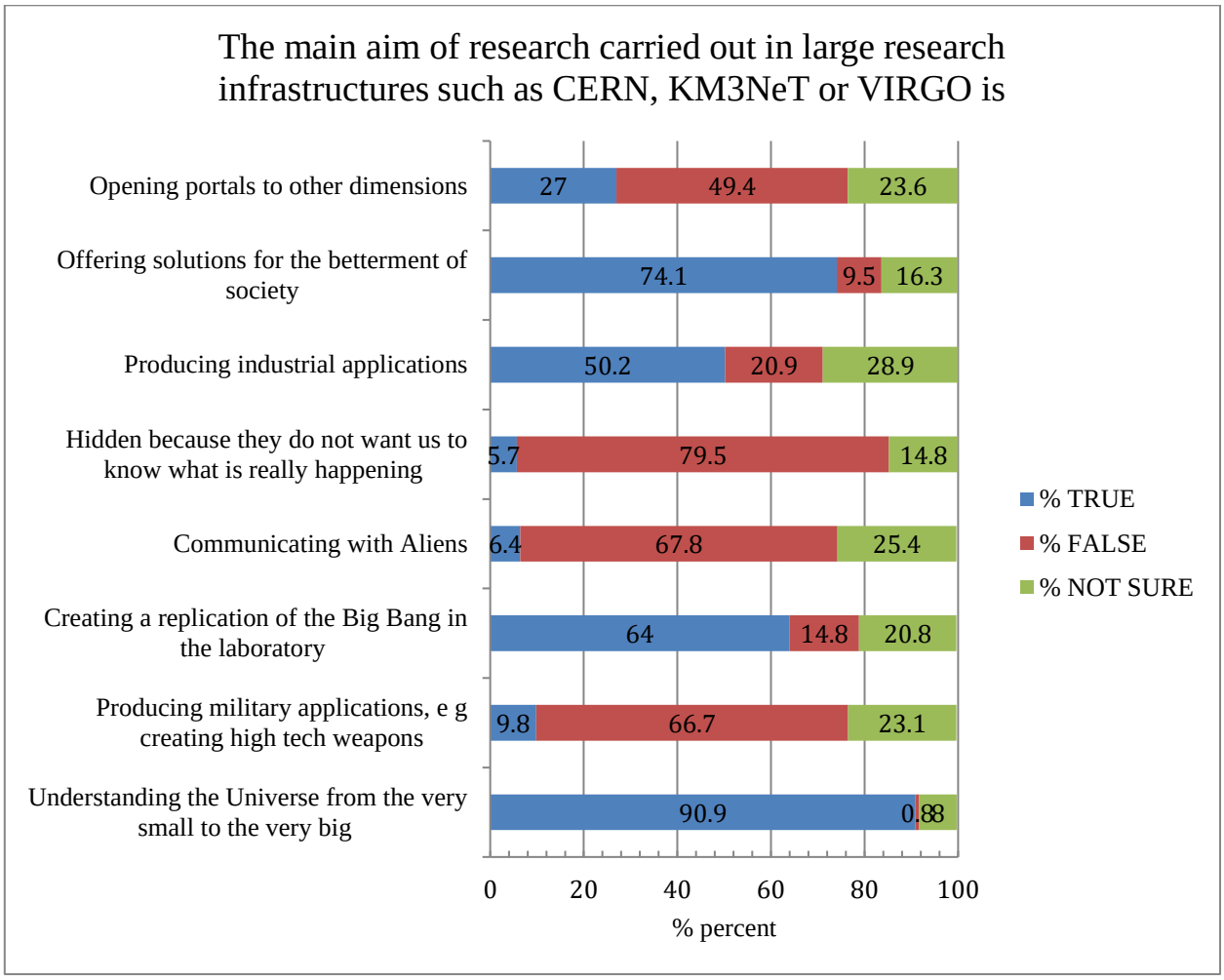

Figure h. Citizens' perceptions on the main mission of large research infrastructures in Physics

The respondents have correctly assessed that the main aim of large research infrastructures in Physics is to understand the universe from the very small to the very big. The offering of solutions for the betterment of society, one of the most important missions of LRI's is also correctly assessed as such. Potential spinoff outputs such as the production of technological outputs and industrial applications has also been identified correctly.

However, it is important to state that a small minority of respondents consider that LRI's main mission is the production of military applications, communication with aliens, opening portals to other dimensions and most notably, that the main mission is "Hidden because they don't want us to know what is happening". The latest statement is one of the most prominent anti-scientific beliefs that one can occasionally encounter in social media and news posts regarding fundamental science. As expected, such beliefs are very limited in this highly educated sample, yet they are not vanishing. This statement reinforces our conviction that public perceptions of fundamental research can be improved and REINFORCE is prepared to work towards this goal with the proposed engagement activities. With the increase of statistics of the survey, safer results will be able to be obtained.

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Having identified our sample in this survey, we proceed in the identification of their interest to contribute to the REINFORCE demonstrators, their main motivations as well as the factors they consider important in order to sustain their engagement.

Interest to contribute to REINFORCE Demonstrators

The participants of the survey were asked to state their interest to contribute to each REINFORCE demonstrator, answering a 5 point Likert scale questionnaire (1: Not interested at all – 5: Very interested). The results per demonstrator can be found in the following figure.

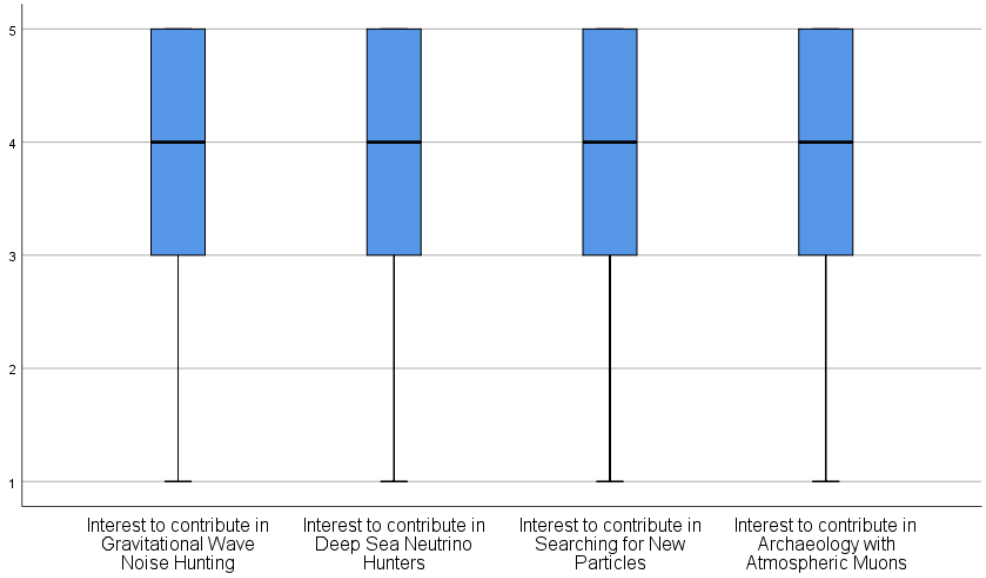

Figure i. Interest of respondents to contribute in each REINFORCE demonstrator

We observe that respondents' interest is high and that no significant changes are observed between demonstrators. The overall interest of respondents to contribute to REINFORCE is presented in the following histogram.

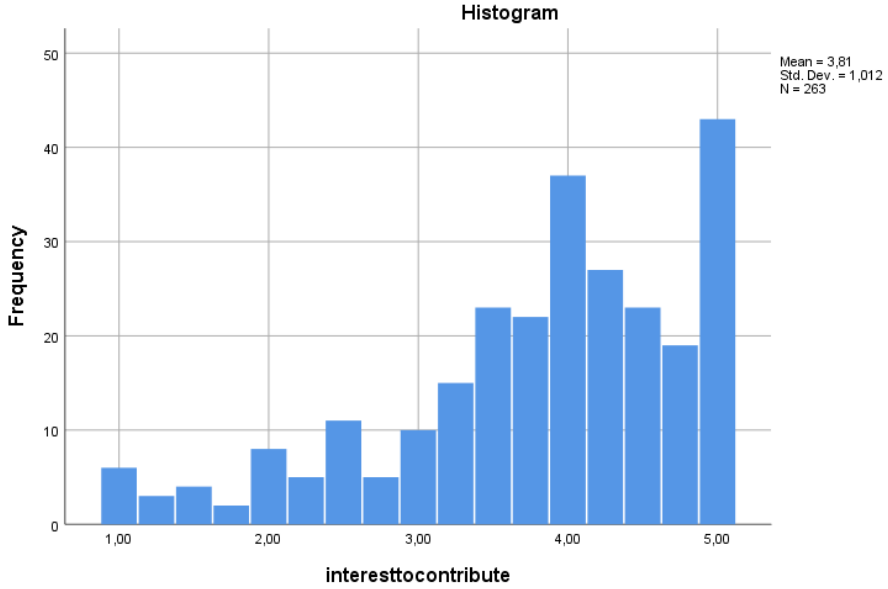

Figure j. Respondents' interest to contribute to the REINFORCE demonstrators.

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Further analysis demonstrated that no significant differences are observed with respect to gender. Citizens with stronger science background seem to have an overall higher inclination to contribute to the REINFORCE projects of the order of 13%. With the increase of statistics of the survey, safer results will be able to be obtained.

Citizens' motivations to participate in REINFORCE

In order to investigate the participants' main motivations to participate in REINFORCE, a series of proposed motivations coming from the bibliographic research have been identified.

Table C: List of citizen motivations

- I believe that I can contribute to scientific research
- I am interested in working with the data that even scientists have not analyzed yet.
- I am fascinated that I might help to make discoveries
- I find the topics of the projects very appealing
- I expect to learn more about the process of cutting-edge science
- I expect to acquire a greater purpose for learning about science topics
- I feel good to be involved in such scientific practices
- I am interested in connecting the work with my professional activities, e g teaching in my class
- I am interested to become more involved in the projects' topics
- I believe I can successfully contribute to the projects' tasks
- I will have the chance to interact with scientists throughout my participation
- It will increase my social standing among colleagues, friends, and family
- It provides me with an opportunity to share my interest in social media, with friends and colleagues
- I want to become part of a community of like-minded people
- It seems like a fun activity to do

The participants answered a 5-point Likert scale questionnaire (1: Strongly Disagree – 5: Strongly Agree), the results of which are summarized below.

Overall, all the primary motivations of citizens, identified by our bibliographic research seem to be present within the sample of our survey with citizens agreeing on the majority of them. We observe that on average, motivations relevant to social standing and sharing with colleagues and social media don't seem as important as "helping to make discoveries" and "expecting to learn a lot about cutting edge science" which are the main motivations of the respondent citizens.

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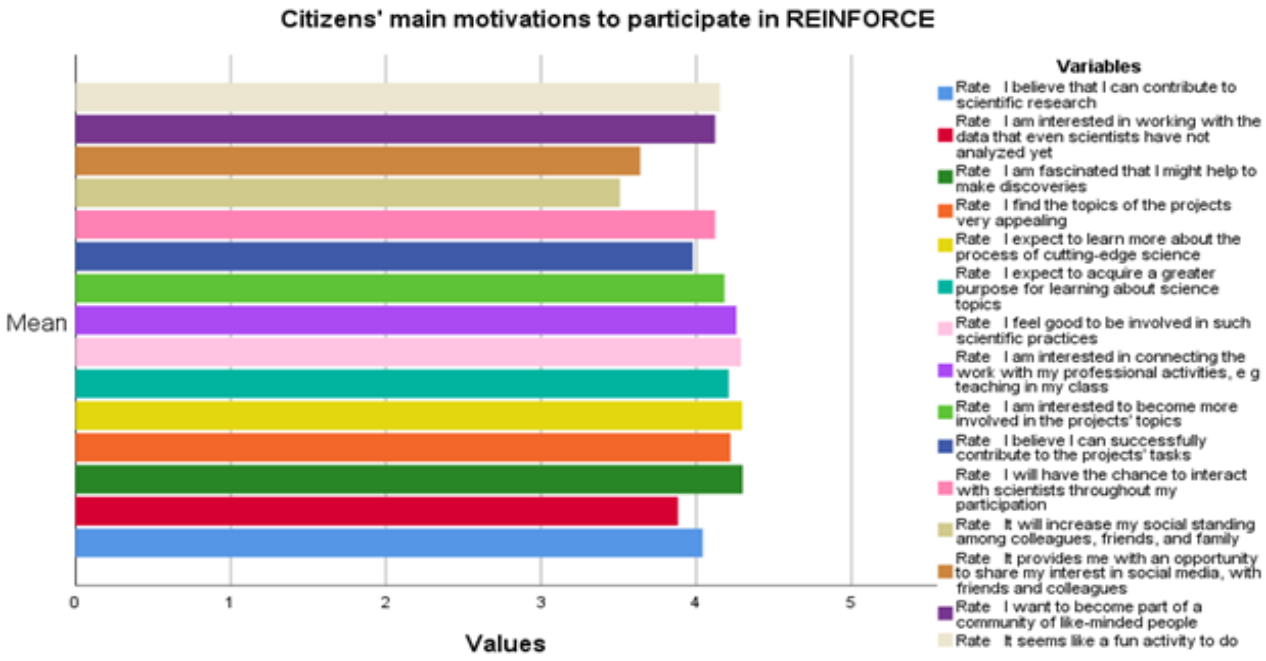

Figure k. Citizens' main motivations to participate in REINFORCE

The structure of the survey allows us to differentiate between different sub-groups.

- With respect to gender, no significant difference is observed between male and female citizens.
- Citizens with prior experience in citizen science and specifically involvement in projects related to Physics or Astronomy (N=41) appear to : agree more than the average that: "They are interested in working with the data that even scientists haven't analyzed yet"; "They believe that they can contribute to scientific research"; "They believe that they can successfully contribute to project tasks"; "It provides them with an opportunity to share their interest in social media with friends and colleagues".
- A small portion of citizens (N=7) seem to have antiscientific beliefs (Identified as the citizens who offered the following answers to the questions: Astrology is an integral part of science: True | Not sure & Evolution is correct: False | Not Sure && Research Infrastructures don't want us to know what they do: True | Not sure), even though the professional activities of the majority are connected to science. According to their answers, they tend to believe less than the average that "they can contribute to scientific research". "Increase of social standing among colleagues, friends and family" as well as "opportunity to share their interest in social media with friends and colleagues" seem to be more important to them compared to the average.
- A sub-group (N=23) of citizens with strong science background was examined: (Degree >=BSc; Non anti-scientific beliefs; work related to natural science; very into science; science has benefitted me personally). They agree more than the average that:

"They feel good to be involved in such scientific practices"; "they are fascinated that they might help to make discoveries" and "they believe that they can contribute to scientific research".

Factors that can sustain citizens' engagement

This section identifies the main factors that are expected to affect citizens' sustained engagement in REINFORCE. The participants answered a 5 point Likert scale questionnaire (1: Strongly Disagree – 5: Strongly Agree), the results of which are summarized below.

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Figure l. Main factors that can affect citizens' sustained engagement in REINFORCE

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Overall, all aforementioned factors are considered quite important or more, with the factors: "Getting feedback", "Understanding the scientific impact of their work", "Receiving training" and using an "interface that is easy to manipulate" can be considered as the most important messages. With the increase of statistics of the survey, safer results will be able to be obtained.

Summary of the findings of the present survey

The purpose of this survey was to identify the potential target groups of REINFORCE, explore their characteristics and investigate: a. their interest to contribute in REINFORCE; b. their primary motivations in order to participate in REINFORCE projects, following the outcomes of the bibliographic study; c. the factors that can affect their sustained participation in the REINFORCE citizen science projects. The analysis presented here corresponds to 263 respondents, 62.9% of which were female and 37.1% male. This survey is an ongoing process and the results reported here can be considered preliminary, yet enlightening. With the increase of statistics of the survey, safer results will be able to be obtained.

Table D: The main findings of the citizens' survey in REINFORCE

Identification of participants
• The majority of the participating citizens have a strong educational background, having acquired at least a Bachelor's degree • The majority of the participants (57%) are aware of citizen science. • 36.4% of participants work in fields relevant to Natural Sciences. • The majority of the participants answered that they are "very into science" or "quite like science". They agree or strongly agree that science has a positive impact to society and to them personally. • The majority of participants answered adequately a series of general science knowledge questions, with the exception of a question regarding astrology and whether it is scientific in which more than 28% answered yes, indicating a misconception regarding this issue.
Familiarity of participants with the science, mission and work of Large Research Infrastructures (LRI) in Physics
• The participants were mildly familiar with vocabulary items relevant to the demonstrators of REINFORCE. • More than 65% of the respondents feel confident to explain what CERN does to a friend, only 27% feel confident to explain about VIRGO and 13% about KM3NeT respectively. • The respondents have correctly assessed that the main aim of large research infrastructures in Physics is to understand the universe from the very small to the very big and have correctly identified the mission of betterment of society. • There seems to be a knowledge gap in a minority of the respondents who indicate that LRI's main mission is the production of military applications, communication with aliens, opening portals to other dimensions and most notably, that the main mission is "Hidden because they don't want us to know what is happening".
Interest of participants to contribute in REINFORCE
• Respondents' interest is high and that no significant changes are observed between demonstrators. No significant differences are observed between genders, while more scientifically oriented citizens display higher inclination to participate.
Participants' primary motivations to contribute in REINFORCE
• On average, motivations relevant to social standing and sharing with colleagues and social media don't seem as important as "helping to make discoveries" and "expecting to learn a lot

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about cutting edge science" which are the main motivations of the respondent citizens. No significant changes are observed with respect to gender. • Participants with prior experience in citizen science are motivated by the opportunity to contribute to scientific research, by the opportunity to work with new data and feel more confident than the average to contribute in the project tasks. • Participants with strong scientific background display the same characteristics, with the addition that they "feel good to be involved in scientific research and are fascinated that they might make discoveries." • Participants who seem to have anti-scientific beliefs display lower confidence than the average that they can contribute in science and higher motivation to share their results with their peers and increase their social status.
Factors that can sustain participants' engagement
• All factors selected by the bibliography are on average equally important to the respondents. • "Getting feedback", "Understanding the scientific impact of their work", "Receiving training" and using an "interface that is easy to manipulate" can be considered as the most important factors that can influence their sustained engagement.

The aforementioned findings indicate that the citizen engagement strategy of REINFORCE must address all the proposed citizen motivations horizontally as their importance is overall equal to the citizens.

Discussion

Our sample so far consists of respondents of age 25-54 years old with advanced educational profiles, with good disposition towards science and on average a prior exposure to citizen science. This demonstrates that the sample so far is not inclusive, yet it shows who are the users that are most likely to participate in REINFORCE. As the goal of the project is to enhance its inclusion, the engagement strategy takes into account these features and proposes the roadmap by which scientific efficiency and inclusion can be balanced.

The majority of the topics introduced by REINFORCE are quite novel and might be difficult to understand by the respondents. In this framework, REINFORCE needs to focus explicitly on the educational aspects of its demonstrators, offering high quality educational resources and organizing participatory activities that will support citizens' training in these issues.

Public perceptions of fundamental research can be improved as it can be seen from answers relevant to "how scientific astrology is" or about "obscure aims of Large Research Infrastructure". Throughout its engagement strategy and its educational content, REINFORCE is prepared to work towards this goal.

The REINFORCE project has received funding from the European Union's Horizon 2020 project call H2020-SwafS-2018-2020 funded project Grant Agreement no. 872859

Detailed Task analysis Report (ZSI)

Gravitational Wave Noise Hunting

Scientificity

Which scientific question, hypothesis or goal is to be answered, tested or achieved with your demonstrator project?

The main goal is to classify the noise features in the Gravitational Wave Noise Detectors, such as glitches, but not only. A glitch is a transient signal produced by instrumental noise. They are spurious signals in the channel that we normally use to look for gravitational waves (this channel is called gravitational wave strain channel and is indicated by the label h(t)). Where do these glitches come from? We know that they originate in the various subsystems of the detector, and therefore we monitor each part of the full Virgo interferometer with dedicated devices, each one produces a continuous strain of data. We call these data from these devices' auxiliary channels, since they are helpful to understand the behaviour of the detector and in part they are also used to reconstruct the signal produced by a gravitational wave.

We would like to classify and characterize also other noise features, and possibly identify how the auxiliary channels impact on the h(t). The goal is to have a dataset of classified noise features for Virgo and possibly the other interferometers.

Which scientific methods are applied in your demonstrator project? Please describe them briefly.

We will mainly use the machine learning approach using the time-frequency representation of the noise in the Gravitational Wave interferometers that we can convert to images or sounds and use as input for the classification.

Which new knowledge is generated in your project, e.g. which improved explanation of certain contexts is created, or which new method is developed in your project?

The output of the demonstrator will be a better knowledge of the noise in Virgo, thus helping in improving the detector range and increase the number of detections.

Participants

Which target group(s) will the project address (in terms of age, gender, profession, stakeholder group), specific groups (elderly, visual impairment, pupils, etc.)?

We aim mainly at people interested in gravitational wave science. This could involve all age groups, from students to elder people. We would like to implement a "sonification" part to involve also the visually impaired people.

Which requirements are needed on the participant's side?

(a) in terms of infrastructure (e.g. Computer, Internet, Software, research instruments) (b) in terms of skills and scientific knowledge?

Computer, and internet connection

Knowledge of the different appearance of noise features, which will be provided in a specific training session on the web. Involving children could be an interesting possibility. We can think about more game-oriented activities for children. About visually impaired people we have, as part of the WP, the idea of converting the glitch data not only to images but also to sounds.

Collaboration Task(s)

What added value is generated for all participants:

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(a) for the citizen scientists? What will they gain and learn?
(b) for the scientists?

They will learn the various details on how the noise can impact on a scientific measure, in this case the observation of gravitational waves, and be updated with the status of the detector

There will be an updated dataset of the noise features that will be useful for the training of the machine learning algorithm that we plan to use for discriminating glitches from real signals.

Why is it not possible to achieve the project goals without the cooperation of the citizen scientists?

The basic ingredient for training the machine learning algorithms is to have a dataset of labelled samples, and this could only be achieved with the help of dedicated people that look at the noise features and classify them.

In which project element(s) do the citizen scientists work? Please mark which project elements apply (multiple answers possible)

Common elements of research projects usually include[5]:

Search for a topic and formulation of research questions

Data collection

Please describe shortly the (different) task(s) and workflow(s) that the participants will perform:

The users will be presented with a representation of the noise in a specific timeframe (e.g. 10 seconds) and will be asked to identify and encircle all the relevant features and tag them (e.g. glitches). This input will then go to a database of labelled features that the machine learning algorithm will use as a basis for the training.

@ Search for a topic and formulation of research questions: An intriguing possibility could be trying to understand the statistical properties of these glitches and their general behaviour, such as “how many they are? When they occur the most? Day or night time?” Etc.

@ Data collection: by participating in the activities, the citizens will help to gather labelling on each glitch.

Please classify the nature of the task(s). Please mark what applies (multiple answers possible)6:

Contribution task(s): the citizens contribute to the project with performing tasks

Can you estimate the time (e.g. in hours) that citizens are expected to spend on the task; is there a minimum time resource necessary?

This is hard to estimate, but I think that after a 1-hr training session, the citizens will be able to work independently and start classifications. There is no minimum time, in the sense that once learned the tasks, it could be performed in a few minutes per glitch.

Initially, I was thinking more to some video tutorials for the first part, and then, later on, we could plan some dedicated F2F training meetings.

How will the participants learn to perform the task? (e.g. training, learning by doing)

We plan to prepare a set of training webpages, and possibly online videos. The rest will be learning by doing, in the sense that they will learn as soon as they will classify more things.

Open Science

[5] Note: only the selected items are listed below
[6] Note: only the selected items are listed below

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Where will data and metadata be made publicly available? If there are legal or ethical arguments against doing so, please explain them briefly.

The data that is used to produce the noise is already public under the policy of the LIGO and Virgo collaboration and are made public after a certain amount of time after the data has been acquired. We can think of releasing also the data that have been labelled, depending on how the LIGO and Virgo collaboration will decide on it.

Where will the results be made publicly available so that they can be found, reused, comprehensible and transparent? If there are legal or ethical arguments against doing so, please explain them briefly.

The output of the research can be made public through a specific website, as it happens already for other projects such as gravity spy.

Communication

How are the various interest groups addressed in an appropriate way?

Once the demonstrator will be ready and the documentation will be finished, we plan to activate a set of social accounts so that they can be used to spread the news and the results related to our projects, also via the outreach tasks of Reinforce.

We have within the Department of Physics, INFN and EGO, a lot of contacts with schools in Italy and abroad, so we could start a newsletter and involving these schools for a start.

How can participants contact the project team and give feedback and where can they find this information? (e.g. email, address, contact form)

We plan to give contacts on the website, e.g. emails, and possibly via the contact form.

Which different roles are there in the project and where are they described?

We foresee the main role of citizen science as a person that will participate in the classification. Regarding the organization of the project, we think that it will reflect the organization of the work package, with responsibility of the project and with people that will take charge of specific tasks, such as the communication and the development of the infrastructure.

We are in the phase of defining them, however, I foresee these, apart from the standard roles are PM:

Machine-learning developer & expert in analysis

website manager

communication manager

In which way will the participants receive feedback on the results and progress of the project? (e.g. newsletter, blog, information event, scientific publication)

There will be updates on a blog on the main website, and we plan to prepare scientific publications based on the outcome of the classification.

I think we could have some posts on the university and EGO portal, but then on a specifically designed website is the best option.

Ethics

How are the projects goals compliant with fundamental ethical values (including respect for human rights and fundamental freedoms)?

The project will guarantee participation for all people that are interested in contributing to this scientific endeavour, and will, of course, avoid any form of discrimination. The contribution that the volunteer will give will be used in the sole interest of advancing our knowledge of gravitational wave physics.

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Please reflect on the ethical aspects of your project. For example, is there a reflection on diversity, inclusion, or gender equality about inclusion or exclusion of specific groups; self-obligatory information texts, etc.?

I think that one of the main drivers of this project is to provide access to the citizens to the data that the scientific community is gathering in this area, showing that the science is inclusive not only concerning for the scientists but also to the outside community. This is organized in such a way to include all people that can be interested regardless of any form of discrimination and with the only main goal to involve people in the scientific endeavour

We will start collecting information from schools and then we will have a subscription webpage for people that are interested in taking part to the project.

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Deep Sea Hunters

Scientificity

Which scientific question, hypothesis or goal is to be answered, tested or achieved with your demonstrator project?

For the first time, in-situ deep sea data acquired with the sensors incorporated in the ANTARES and KM3NET neutrino telescopes will be made available to the public to study the biological activity in the vicinity of the detectors. Light signals from bioluminescent organisms and acoustics signal from cetacean mammals will be analysed with the goal to classify the characteristic emission patterns and their variation as a function of day and season as well as ambient environmental parameters such as sea current, oxygen level, etc.

The results of the classification will be compared with the outputs of a machine learning algorithm designed to disentangle the different components of the noise data recorded by KM3NeT. A good comparison between the results will ensure that the algorithm is working as expected (no over-training, correct classification, …). Each class of events will then be used in interdisciplinary projects together with biologists or geophysicists, ensuring an extensive and long-term use of the work performed by the citizen scientists.

Which scientific methods are applied in your demonstrator project? Please describe them briefly.

The sequences of time series data from the optical modules will be presented via a Zooniverse webpage interface. The citizen scientist will be asked to classify the various the 'waveforms' observed (single peak, double peaks, multiple peak, weird, short duration, long duration). In parallel computer algorithm will also be developed to do similar classification and compare with the citizen scientist classifications.

Sequences of acoustic time/frequency spectrogram data from the acoustic hydrophones will be presented via a Zooniverse webpage interface. The citizen scientist will be asked to classify the various the 'waveforms' observed (clicks, chirps, dolphin, whale, shipping, acoustic calibration, other). In parallel computer algorithm will also be developed to do similar classification and compare with the citizen scientist classifications.

For both cases, correlations with other parameters will be investigated.

Which new knowledge is generated in your project, e.g. which improved explanation of certain contexts is created, or which new method is developed in your project?

The bioluminescence data has never been studied to such an extent previously, so this is a completely new research topic and everything done will be new knowledge.

For the acoustic data, a previous study has been performed on a relatively limited dataset. We hope to extend to a larger sample and develop better classification methods.

Participants

Which target group(s) will the project address (in terms of age, gender, profession, stakeholder group), specific groups (elderly, visual impairment, pupils, etc.)?

We think the citizen scientist tasks can be performed by essentially anyone with good visual skills. In principle the data could be sonified, opening it up to the visual impaired.

Also, sonification of optical data is envisaged in the framework of a collaboration with an artist (Donald Fortescue).

Which requirements are needed on the participant's side? (a) in terms of infrastructure (e.g. Computer, Internet, Software, research instruments) (b) in terms of skills and scientific knowledge?

The participant will need access to the Zooniverse website. No specific software will be needed apart from those already present on the Zooniverse platform. Speaker will also be needed for the sonified data.

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No special scientific knowledge is required.

Collaboration Task(s)

What added value is generated for all participants: (a) for the citizen scientists? What will they gain and learn? (b) for the scientists?

Sensitisation to the scientific method, the basic concepts of data analysis and the principles of machine learning. Appreciation of the biodiversity in the deep sea, even at such extreme depths. Contribution to pioneering studies.

Help in processing a large data set. The classifications are not so obvious from the beginning. The scientists in our team will develop machine learning algorithms whose outputs will be compared to the results obtained by the citizen scientists.

Why is it not possible to achieve the project goals without the cooperation of the citizen scientists?

The main goal is to contribute to the optimisation of machine learning (ML) techniques for the identification of different classes of events in the data collected by KM3NeT. This approach will include the identification of the most relevant parameter to be used in the ML algorithm, a task requiring manpower and dedication.

In which project element(s) do the citizen scientists work? Please mark which project elements apply (multiple answers possible)

Common elements of research projects usually include[7]:

Data analysis and interpretation

Please describe shortly the (different) task(s) and workflow(s) that the participants will perform:

Task 1: Event classification
The participants look at each event and study the value of the parameter list together with the external conditions recorded at the time of the event. Based on their observations, they classify it in one of the predefined categories of events.

Task 2: Peer reviewing of the classification
The participant's review (possibly in a blind way) some of the events classified by other participants

Task 3: Search for new parameters
The participants search for new parameters that have potentially interesting discrimination power and propose them to be added to the classifying algorithm

Task 4: Identification of most performant discriminating parameters
The participants evaluate the discriminating power of each parameter and identify the most performant ones

Tasks 3 and 4 will be accessible only to participants who have performed a minimal number of event classifications and reviewing

Please classify the nature of the task(s). Please mark what applies (multiple answers possible)8:

Contribution task(s): the citizens contribute to the project with performing tasks

Can you estimate the time (e.g. in hours) that citizens are expected to spend on the task; is there a minimum time resource necessary?

The tasks 1 and 2 can be performed on blocks of events of a specific size, that will be adjusted for an approximate duration of 15 minutes. The participants can process as many blocks as they want.

[7] Note: only the selected items are listed below
[8] Note: only the selected items are shown below

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How will the participants learn to perform the task? (e.g. training, learning by doing)

For each task, a tutorial will be presented when the participant enters the corresponding module. It will describe the event format and explain the meaning of the different parameters, and explain the scientific method underlying the task.

Open Science

Where will data and metadata be made publicly available? If there are legal or ethical arguments against doing so, please explain them briefly.

New datasets will be periodically released on the Zooniverse platform. Real-time is not envisaged because of the time needed to preprocess the data into a Zooniverse-compatible format.

Where will the results be made publicly available so that they can be found, reused, comprehensible and transparent? If there are legal or ethical arguments against doing so, please explain them briefly.

Along with the project, the classified events will always remain accessible to the participants and be reinjected into the classification scheme for peer review (task 2). Summary information will be generated and presented on the main project webpage, describing the statistics of events processed and classified, the main parameters identified and added to the selection procedure.

Also statistics concerning the profile of the project participants will be provided (e.g. in terms of age and gender groups, average time or a number of events processed per participant). At the end of each participant's session, a summary is shown.

Communication

How are the various interest groups addressed in an appropriate way?

All tasks can be performed by any participant.

The *Deep-Sea Hunters* activity will be promoted during the outreach events organized by the institutes and universities part of the KM3NeT Collaboration. This will allow reaching potential participants in 18 countries around the world. We will also advertise the activity on the website and social media platforms of KM3NeT to reach scientists and other particle physics collaborations. In addition, the activity will be presented during events organized in schools or in front of a young audience, potentially in the framework of Masterclasses.

How can participants contact the project team and give feedback and where can they find this information? (e.g. email, address, contact form)

A "question" page on the website (contact form) will be provided.

Which different roles are there in the project and where are they described?

Concerning the citizen scientists: Different levels of participants can be defined based on the time spent on the project (e.g., in terms of a number of events classified, …). Participants with a sufficient level of experience can acquire a specific status and act a referent for other, less experienced participants (e.g., by answering their questions through discussions in the chat feature of the Zooniverse platform. Additionally, the participants that have the best personal statistics (the most classified events, etc) might be asked to join a call with some members of the demonstrator teams to discuss the comparison with the machine learning algorithm, or the ranking of variables, towards the end of the project.

Concerning the scientists involved in the REINFORCE project: All the members discuss together to develop the different tasks and the implementation within ZOONIVERSE. The postdocs involved in the project are taking care of selecting the required data.

In which way will the participants receive feedback on the results and progress of the project? (e.g. newsletter, blog, information event, scientific publication)

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Global Information presented on the project main webpage and updated in real-time (number of classified events, number of reviewed events, etc)

Summary with statistics at the end of each participant's session → possibility to be discussed with the people in charge of Zooniverse

The results of the classification will be used to collaborate with marine biologists and may, therefore, be the topic of a joint publication that will be shared with the citizen scientists.

Ethics

How are the projects goals compliant with fundamental ethical values (including respect for human rights and fundamental freedoms)?

All tasks can be performed by all participants, and blindly; the participants will therefore not have any information on the profile of other users.

Please reflect on the ethical aspects of your project. For example, is there a reflection on diversity, inclusion, or gender equality about inclusion or exclusion of specific groups; self-obligatory information texts, etc.?

Global statistics will be advertised on the project webpage to communicate on the diversity of participants.

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Search for new particles at the LHC

Scientificity

Which scientific question, hypothesis or goal is to be answered, tested or achieved with your demonstrator project?

Citizens will explore data collected from the Large Hadron Collider of CERN to search for new elementary particles and physics mechanisms that would extend our knowledge of particle physics beyond the well-established Standard Model, highlight revised directions for future research, and provide clues for some of the open scientific questions (e.g. the origin of dark matter).

Which scientific methods are applied in your demonstrator project? Please describe them briefly.

Citizens will search for evidence of undiscovered particles among a sample of proton-proton collision data recorded with ATLAS, one of the two large experiments operating at the Large Hadron Collider (LHC) of CERN. For this purpose, the event-display and visual-data-analysis software HYPATIA will be used. The project will finally be integrated into the Zooniverse platform.

Which new knowledge is generated in your project, e.g. which improved explanation of certain contexts is created, or which new method is developed in your project?

The discovery of the Higgs boson in July 2012 by ATLAS and CMS, the two large experiments operating the LHC of CERN, was a major scientific achievement and the culmination of more than 40 years of theoretical and experimental research into the Standard Model (SM) of particle physics. While the SM Higgs boson has been discovered, there are several theories Beyond Standard Model (BSM), such as supersymmetry, which open a window for even more significant discoveries. Citizens will look for new particles predicted by such BSM theories; their search can lead to the discovery of one such particle which will be proof of new physics.

Participants

Which target group(s) will the project address (in terms of age, gender, profession, stakeholder group), specific groups (elderly, visual impairment, pupils, etc.)?

The project is oriented towards citizens above 15 years old, of any gender, profession etc., with curiosity for discoveries. We are addressing the same target group as the Zooniverse platform with its 1.2 million followers.

Unfortunately, though, the nature of the WP (which is visual data analysis) makes it rather difficult to accommodate users with visual impairments; potential solutions will be taken into consideration. On the other hand, users with hearing impairments will have no problem performing the search.

Which requirements are needed on the participant's side? (a) in terms of infrastructure (e.g. Computer, Internet, Software, research instruments) (b) in terms of skills and scientific knowledge?

A computer, connected to the internet.

All necessary scientific knowledge will be provided with tutorials embedded into the Zooniverse platform. References to additional bibliography will be included for those who are interested in extending their knowledge beyond the scope of the project.
Regarding prerequisite knowledge, familiarity with basic high-school-level physics concepts, such as the structure of matter, will be assumed. We specifically intend to present the project and invite students to perform the tasks during periodical visits to schools for F2F masterclasses. In principle, some of the steps could be performed without any prior knowledge of physics, but they would just consist of following instructions, without any understanding. Extended bibliography will be referenced for those users to look up in order to reach a level where they would understand more.

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Citizens are the end-users of WP5; the details of their workflow are being discussed (along with the development of the tools and data sets) even though technically all this should start on M6 of the project. The comparative analysis of citizens' results versus ATLAS scientists' results, at higher-level tasks, may lead to the improvement of the algorithms used by the latter. The Zooniverse project has published some papers, based on the citizens' "discoveries" in collaboration with the relevant scientists.

Collaboration Task(s)

What added value is generated for all participants: (a) for the citizen scientists? What will they gain and learn? (b) for the scientists?

The citizens will be introduced with the methods of scientific investigations, since they will be actively engaged in "real" searches for new phenomena, including acquisition of information on a given scientific problem, execution of a search, and drawing of conclusion and discussion with fellow citizen researchers. This way they will be able to experience the work done in large scientific infrastructures which are supported by the taxpayer contributions.

The scientists will compare the citizens' findings with theirs and may find ways to improve their search-for-discovery algorithms.

Why is it not possible to achieve the project goals without the cooperation of the citizen scientists?

Algorithms looking for new particles of various kinds already exist but are usually tuned to look for specific signatures. People can notice unusual or unexpected data that would be missed by algorithms. With the aggregation of data from thousands of citizen Scientists, we can produce findings (histograms) that may indicate the possible existence of new particles. Those results can also help the ATLAS researchers to improve their algorithms.

In which project element(s) do the citizen scientists work? Please mark which project elements apply (multiple answers possible)

Common elements of research projects usually include[9]:

Data analysis and interpretation

Publication and communication of results (i.e. citizens are actively involved in the writing of the publication).

Please describe shortly the (different) task(s) and workflow(s) that the participants will perform:

Citizens are the end-users of WP5; the details of their workflow are being discussed (along with the development of the tools and data sets) although technically all this should start on M6 of the project. The comparative analysis of citizens' results versus ATLAS scientists' results, at higher-level tasks, may lead to the improvement of the algorithms used by the latter. The Zooniverse project has published some papers, based on the citizens' "discoveries" in collaboration with the relevant scientists.

Please classify the nature of the task(s). Please mark what applies (multiple answers possible)10:

Contribution task(s): the citizens contribute to the project with performing tasks

Collaborative task(s): the tasks are performed together

Can you estimate the time (e.g. in hours) that citizens are expected to spend on the task; is there a minimum time resource necessary?

[9] Note: only the selected items are listed below

[10] Note: only the selected items are shown below

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Citizens can perform searches anytime from anywhere (online only). The searches will be divided in stages of increasing difficulty. Each stage will have its instructions and tutorial, which the citizen scientists will have to study to perform the corresponding task. The time they will then spend on the project will depend on the number of "events" they wish to investigate in each session. In the first stage, each "event" will require about a minute to investigate, but in the last stages, it will take much longer depending on the complexity.

How will the participants learn to perform the task? (e.g. training, learning by doing)

They will be given detailed instructions for each stage of the project. They will also be trained with event signature examples produced by simulations of the new particles they are looking for. As our goal is to reach thousands of users, most trainings will be through online material that we will provide in the Zooniverse platform (examples can be provided by documentation, reference to articles, videos, etc.). F2F training will be only done in very few cases during visits to schools.

Open Science

Where will data and metadata be made publicly available? If there are legal or ethical arguments against doing so, please explain them briefly.

The data used by WP5 is already publicly available as a part of CERN Open Data (http://opendata.cern.ch/), and represent a significant portion of the overall LHC-recorded data.

Where will the results be made publicly available so that they can be found, reused, comprehensible and transparent? If there are legal or ethical arguments against doing so, please explain them briefly.

The results of the investigation both by the citizen scientists and by the automated tools that will be developed as part of WP5 will be made available on the Zooniverse platform. A comparison of both datasets will be performed where possible. Any possible findings will be published.

There will be no personal data collected for WP5 except those already collected by the Zooniverse platform.

Communication

How are the various interest groups addressed in an appropriate way?

The projects will be advertised on social media and their tracking aspects may provide information about the demographics of the citizens engaged in the searches. All of these steps will be taken care of by the Zooniverse platform.

How can participants contact the project team and give feedback and where can they find this information? (e.g. email, address, contact form)

We will develop and guide the community of users through the Zooniverse portal, as well as the project's social media. They could communicate any unexpected features through a forum in Zooniverse, which the scientists will regularly visit and use to provide feedback. Users will be able to not only receive feedback but also draw our attention to interesting events worth of further investigation.

Which different roles are there in the project and where are they described?

The IASA team will lead the first two tasks (data collection and development of tools). The University of Oxford team will lead the development of the Zooniverse project as well as the development of the comparative analysis (citizens vs. researchers). Additional roles, e.g. researchers providing feedback, will be determined at a later stage with the project.

In which way will the participants receive feedback on the results and progress of the project? (e.g. newsletter, blog, information event, scientific publication)

Feedback will be available through social media channels (e.g. Facebook, Twitter), as well as the dedicated forum on the Zooniverse platform, which the scientists will regularly visit.

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Ethics

How are the projects goals compliant with fundamental ethical values (including respect for human rights and fundamental freedoms)?

Details on ethics are given in the corresponding deliverable of the project. The data collection will be performed through the Zooniverse platform; therefore, ethics applying to Zooniverse (which is included in the ethics document) will apply to WP5 as well.

Please reflect on the ethical aspects of your project. For example, is there a reflection on diversity, inclusion, or gender equality about inclusion or exclusion of specific groups; self-obligatory information texts, etc.?

Everyone is encouraged to participate in the search for new particles. There is no exclusion of any group.

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Interdisciplinary studies with Geoscience and Archaeology

Scientificity

There are two parts in the project:

construction of a low-cost & low-consumption muon detector and

imaging/data analysis implemented on the Zooniverse platform; the data will be implemented there and constantly updated

Which scientific question, hypothesis or goal is to be answered, tested or achieved with your demonstrator project?

The project aims at demonstrating the imaging capability of naturally produced penetrating particles, the atmospheric muons which belong to the secondary cosmic rays.

The topic addresses general questions on imaging techniques with non-invasive and non-destructive methods. Muography is an imaging technique based on the use of muons, elementary particles (without sub-structures), whose properties are close to the ones of the well-known electrons.

The added value may arise either from the ideas on the tracking algorithms (e.g. expert participation level). A “muon challenge” will ask for solutions to inflate artificially the rate of detected muons (fixed by mother Nature) to improve the quality of the images but by keeping as close as possible to the reality. This bonus game should be similar to the “Netflix challenge”.

Which scientific methods are applied in your demonstrator project? Please describe them briefly.

The demonstrator uses the muography methods, similar to the medical X-ray imaging techniques but with different particles and different detection devices.

Brief description of the muography method:

In detail, muons are heavier than electrons (200 times) and unstable (they decay after a couple of micro-seconds). They have been discovered almost a century ago and are well known from all particle physicists. They are produced artificially on accelerators and colliders. They are also produced in abundance in the atmosphere, after the collision of primary cosmic particles (mainly protons travelling in space) “bumping” on the atmosphere nuclei and producing showers of particles. Among those particles, muons can reach the ground level without being (too much) reabsorbed. At ground level muons constitute ~15% of the so-called “natural radioactivity”.

Their interesting property is their low interaction with ordinary matter. There are indeed capable of crossing a few hundred of meters of standard rocks before being absorbed. The rate of those particles, nearly 1 per square cm per minute at ground level, is quite stable in time (day and night) and well parametrized via analytic functions.

Since muons carry an electric charge, they are quite easy to detect. Many types of detectors are used: plastic scintillators, gazeous detectors, nuclear emulsions etc. The principle of those detectors is based on the fact that a small fraction of the particle’s energy, which is lost when it crosses the active part of the detector, is converted into a detectable signal (e.g. light or charges avalanche). This signal is further readout by a dedicated electronics for transfer and storage.

There are 2 types of muography methods : absorption muography and scattering muography. Absorption muography’s principle is the same as medical X-ray imaging: a beam of particles (X-photons in one case, muons in the other case) is incident on a target and is being partially absorbed according to the particle’s energy and the target’s opacity. The absorption is due to the interaction of the muons with the ordinary matter atoms (electrons and nuclei). If a particle detector is located after the target, it will detect the outcoming flux which reflects the relative absorption by the target. This is the way bones appear in “white”

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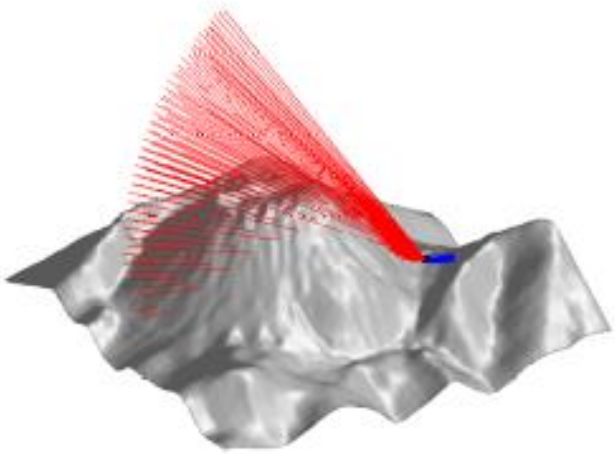
on radiography while muscles appear in greyscale. The contrast on the image reflects the difference in opacity/density of the target's structure (the more opaque, the more absorbing). Absorption muography requires only one detector, located after the target, and the comparison of the measured muons flux with the expected muons flux that should have been measured without the target (reference flux).

Scattering muography implies 2 detectors, with a good angular and spatial resolution, one before the target, one after. The principle is to measure the deviation in the particle's trajectory before and after the target. The interaction of the muons with the charged electrons and nuclei of the matter's atoms induces this deviation in the trajectory of the muons (repulsion/attraction).

Which new knowledge is generated in your project, e.g. which improved explanation of certain contexts is created, or which new method is developed in your project?

These new methods open access to imaging capabilities of large structures, natural or anthropic, and may be used in different applications: non-invasive controls in industries, archaeology, volcanology etc.

Both methods (absorption/scattering) are sensitive to the density of the target. This information is displayed in the form of "muographies" (namely "radiographies with muons"). Since the source of the muons is the atmosphere, they have a broad spectrum that may cross all types of targets, whatever their size. The Figure below displays a volcanic dome, a muon detector (which is quasi point-like at those scales) and the trajectories of the incoming muons which may reach the detector. Some of them cross the target, some are detected directly. And the collection of all trajectories recorded with time allows, after comparison with a model or a reference measurement without the target, to rebuild the distribution of mass inside the target.



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In the industry this technique has been used for the imaging of Blast Furnaces (iron making), Nuclear Power Plants (nuclear cores, radioactive fuel recycling facilities, storage areas), Tunnel Boring Machines. They are used in the fields of civil engineering (buildings structure investigation), mining, heavy industry and power plants.

Participants

Which target group(s) will the project address (in terms of age, gender, profession, stakeholder group), specific groups (elderly, visual impairment, pupils, etc.)?

The groups targeted are very large, including young children at school. Given the simple format of the data (tracks coordinates of the penetrating particles), they may be sonified and addressed to visually impairment.

Examples for children and visual impaired people:
The idea behind this is to provide schools with portable and plug-and-play muons detectors that analyze online the structure of a building (the school for instance) by progressively averaging the contributions of the integrated muons. This is one part of the proposal (outside Zooniverse).

Concerning the visually impaired people the proposal is to build a “cosmic arch”, a 3 layers detector (one horizontal, two vertical) under which people can stand or sit. The data of the muons will be “sonified”, which allows visually impaired people to get a feeling of the muon flux crossing them online. The exercize was initiated for the exhibition “Il ritmo dello spazio” where we build the “cosmic sofa” (picture below).

In the “cosmic sofa” the 2 biplanes detectors register online the muons crossing the target (seating man. @ J.Marteau). The data registered are sonified and may be either visualized or listened to by the public.

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Which requirements are needed on the participant's side? (a) in terms of infrastructure (e.g. Computer, Internet, Software, research instruments) (b) in terms of skills and scientific knowledge?

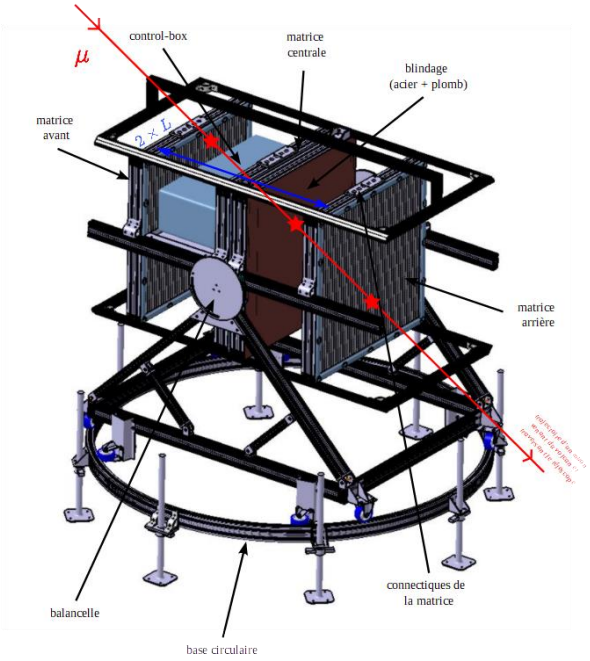
Internet for remote interaction. The detector is autonomous otherwise.

A little bit of particle physics and the basic features of geometry (straight line definition, geometry in space).

Description of an autonomous detector with examples:
The detectors register muons which are produced naturally. Technically they just require a power supply for the readout electronics (typical power is less than 30W, the equivalent of a lamp). They can run with a battery for instance. The electronics are totally autonomous to record interesting events, reject backgrounds, and perform the online imaging.

The detection is performed by putting together at least 3 active square planes. The trajectory is validated 3 aligned hits are coincident in time (within a short time window of the order of a few nanoseconds). In real life, of course, things are not as clean as they should since there could be spurious hits induced by noisy particles, halos of particles accompanying the muons etc. The "game" consists therefore in identifying aligned points in a cloud of points recorded by each plane. This requires basic knowledge of basic geometry.

The scheme of a detector recording a muon trajectory is displayed below.



The images which are produced do not require the injection of particular signals, like in acoustic measurements or X-ray imaging. Particles come from the sky, with a constant rate, and are detected with an autonomous detector. The technique is, therefore, suitable for structural imaging on any field.

Concerning the knowledge in particle physics and basic geometry, there may be different levels. The project can trigger questions on:

the standard model of particle physics (the 12+1 basic constituents of our world, linked by the 4 interactions)

radioactivity (artificial or natural: muons belong to this category)

muons properties (the lifetime of muons has been a proof that relativity was the correct description for fast moving systems kinematics)

muons propagation through the air and the target (mainly straight lines, slightly deviated if the energy of the muon is not too high)

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detection process (scintillation of material, optical fibres, photomultipliers, avalanche effects etc)

detection geometry (in short only a given set of straight lines may reach)

What added value is generated for all participants: (a) for the citizen scientists? What will they gain and learn? (b) for the scientists?

Access to the cosmic rays basic features, as a probe of the atmosphere parameters (pressure, the temperature of the top atmosphere etc.) and as a probe of any target (buildings, underground layers etc.).

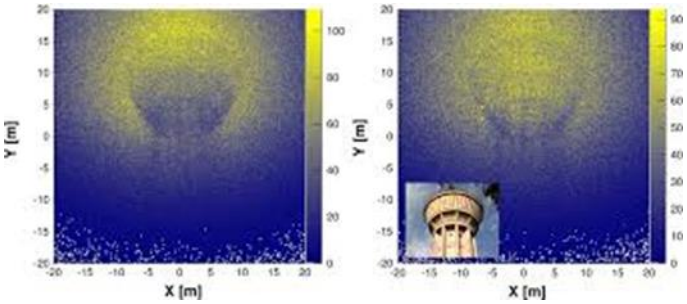
Possibility to perform simple data/simulation comparisons and images by comparing measured to reference muons fluxes.

Why is it not possible to achieve the project goals without the cooperation of the citizen scientists?

The muons imaging science is a multi-parameters field, involving atmosphere physics knowledge, geomagnetism etc. to particle physics, geosciences techniques like inverse problems etc. Gathering all expertizes at the largest scale is a clear advantage to upgrade the method.

Description of muons imaging science:

For image reconstruction, we may have different levels of users: basic, moderate and experts. At the basic levels, we propose to display already reconstructed images and to ask whether they may recognize the imaged structure. For example what do you see below (left picture) ?



At the moderate level, we provide the cloud of points recorded in time coincidence and propose to draw most probable trajectory among those points and compare with reality (there will be an indication with colours reflecting the intensity of energy deposited in the detection planes).

At the expert level, we propose links on methods enabling to recognize the most probable line among the cloud of points (e.g. Hough transform) and give the user to develop his algorithm on track reconstruction.

In which project element(s) do the citizen scientists work? Please mark which project elements apply (multiple answers possible)

Common elements of research projects usually include[11]:

Method design

Data analysis and interpretation

Please describe shortly the (different) task(s) and workflow(s) that the participants will perform:

Method design: develop tracking algorithms, include a priori knowledge to the physics case before analysis, interpret produced images, and perform diagnostic given their own expertize.

[11] Note: only the selected items are listed below

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Please classify the nature of the task(s). Please mark what applies (multiple answers possible)12:

Contribution task(s): the citizens contribute to the project with performing tasks

Collaborative task(s): the tasks are performed together

Can you estimate the time (e.g. in hours) that citizens are expected to spend on the task; is there a minimum time resource necessary?

The minimal task (images interpretation) may require 1-2 hours depending on the images to interpret (building, volcano etc.).

The integration of a priori information requires collaboration between citizens (with knowledge of the field) and scientists (with knowledge of the analysis framework).

The development of tracking algorithms is more difficult and may involve more interaction with target groups on "moderate" and "expert" level.

How will the participants learn to perform the task? (e.g. training, learning by doing)

The best is the interaction with scientists during online masterclass like working with classes or citizen scientists and tracking the muons in the data.

A prototype of exercises will help to learn the methods, e.g. an exercise could be the "imaging" of a school, or a given floor together with the demonstrator and compare or interpret the data together with the teachers and their classes.

Open Science

Where will data and metadata be made publicly available? If there are legal or ethical arguments against doing so, please explain them briefly.

Exchange by web transfer. For public data involving volcano monitoring the confidentiality may be preserved. The images should be displayed on the Zooniverse platform. The data for the tracking analysis should be provided as downloadable files on the platform.

Where will the results be made publicly available so that they can be found, reused, comprehensible and transparent? If there are legal or ethical arguments against doing so, please explain them briefly.

Real pictures corresponding to the muons images should come from publicly available data. They should be published (as answers to the questions) on the same platform. Same stands for the real trajectories of muons among the cloud of points proposed on the platform.

Communication

How are the various interest groups addressed in an appropriate way?

The diverse target groups should be addressed through the project's international network in different languages and the Zooniverse platform.

How can participants contact the project team and give feedback and where can they find this information? (e.g. email, address, contact form)

E-mail to : marteau@ipnl.in2p3.fr

Which different roles are there in the project and where are they described?

Project leader: J.Marteau (IP2I, Université de Lyon) (WP-lead)

Technical responsible: J.C.Ianigro (IP2I, CNRS) (Supervisor of the demonstrator construction and integration)

[12] Note: only the selected items are shown below

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Data Scientists: A.Chevalier, post-doc (responsible for developing/selecting the data sets, the preliminary trackings and images)

In which way will the participants receive feedback on the results and progress of the project? (e.g. newsletter, blog, information event, scientific publication)

The participants will receive feedback through the COMICs Newsletter and the Zooniverse platform e.g. the "muon chat room" (discussion forum).

Ethics

How are the projects goals compliant with fundamental ethical values (including respect for human rights and fundamental freedoms)?

The project gives imaging capabilities in fields with relevant societal impact (natural hazards, industrial risk mitigation etc.), they cope with fundamental ethical values. Some of the data will be collected on sites, where natural/industrial hazards are on the line (e.g. volcanos, industries). These data-enter processes of monitoring and surveillance. They are quite important as far as the societal impact is concerned. This sets also the scale of the "game" we propose to play here.

Please reflect on the ethical aspects of your project. For example, is there a reflection on diversity, inclusion, or gender equality about inclusion or exclusion of specific groups; self-obligatory information texts, etc.?

The project is fully inclusive without any discrimination of any kind. All human beings (and more generally all living forms) are concerned with natural ionizing radiations like muons. The demonstrator recording data, which will be accessible also for people with visual impairments through the sonification process.

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