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European Space University for Earth and Humanity

UNIVERSEH is an alliance of five European universities established to develop a new way of collaboration in the field of Space, within the "European Universities" initiative.

The alliance aims to create new higher education interactive experiences for the university community, teachers and students, and for the benefit of society as a whole. Such initiatives will enable broadminded, informed and conscientious European citizens to capture and create new knowledge and become smart actors of European innovation, valorisation and societal dissemination within the Space sector, from science, engineering, liberal arts to culture.

In Beyond UNIVERSEH, the alliance will develop the research and innovation dimension. By creating a research policy roadmap for 2035 and a vision for 2050 within the space sector, the alliance expects to notably transform the future Space and New Space research landscape, as well to enhance the links between education and research.

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UNIVERSITÉ DU LUXEMBOURG

LULEÅ UNIVERSITY OF TECHNOLOGY

hhu Heinrich Heine Universität Düsseldorf

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1 Introduction/Summary

Science is conducted in a complex social environment and is embedded in a socio-economic, cultural, and political context. As science is also an important source of evidence on which decisions on the issues of our time are based, it needs to be communicated to foster research and innovation. Hence, outreach to society is of central importance and is reflected in research grants that increasingly require communicating research and discoveries to the public as well as in increasing budgets for public engagement in science (e.g. European Framework Program for Research and Technological Development). Both science communication and citizen science are means of bringing citizens and science closer together and increasing the acceptance of science in society. Science communication describes the process of informing the scientific community as well as the public about science and scientific findings. Citizen science involves citizens in scientific research and therefore fosters public engagement.

This report takes stock of already existing structures and experiences in the field of science communication and citizen science. It takes account of the tools and channels implemented in science communication and citizen science activities and collects best practice examples from the AGH University of Science and Technology, the Heinrich Heine University Duesseldorf, the Luleå University of Technology, the Université Fédérale Toulouse Midi-Pyrénées, and the Université du Luxembourg.

The report is structured in five chapters. The second chapter focuses on the underlying understanding of science communication and citizen science as interpreted by each of the five universities mentioned above. The third chapter investigates the institutional structures that promote and support activities in the field of science communication and citizen science. The fourth and fifth chapters present each university's best practice examples of science communication and citizen science in the field of space science and beyond. A conclusion to the report is found in chapter six.

Acknowledgment

We would like to thank all those who have participated in compiling this best practice report. Our special thanks go to all actors of the science communication and citizen science activities presented in this report for sharing their experiences with us.

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2 Definitions of Science Communication & Citizen Science

Communicating science used to be seen as a one-way communication in which scientists informed the public and filled in their knowledge gaps to increase public support - described as the deficit model. It has however developed into a two-way dialogue in which scientists not only convey their research results but also allow the public to provide feedback and their perspectives, therefore taking a larger role in the discussion of scientific research. Many terms such as public exchange, outreach, and knowledge exchange are used to describe this outward-facing science communication. However, not only the terms but also the understanding and use of science communication varies across institutions and nations. Further, science communication can take place in numerous innovative ways on regional, national and international levels and can address diverse publics.

Citizen science is another way to lower barriers between science and the public as it actively involves non-scientists in the knowledge-producing process. Citizen science activities are categorized according to the level of citizen scientists' engagement. The citizen science community distinguishes among four participation levels. While on the first level participants engage occasionally, on the fourth, their engagement is the most comprehensive and includes involvement in the problem definition, data collection, and analysis, hence in all stages of the scientific process. Like science communication, there are various interpretations and understandings of citizen science in Europe, reflecting the culture and context in which they are applied. In contrast to science communication, however, citizen science is not equally known in all countries and therefore defined differently.

As the terms science communication and citizen science may be understood differently among the UNIVERSEH's consortium members, this chapter focuses on the definitions of both terms showing their similarities and differences. It further helps to put the best practice examples presented in the paper into context.

2.1 AGH University of Science and Technology

Although *science communication* and *citizen science* have not been defined by the AGH University of Science and Technology, some activities correspond to the definitions given by the project's partners. A significant majority of them fit the definition of *science communication* and were formally referred to as the *popularization of science*. Few activities are consistent with the definition of *citizen science.* Although citizen science has not been implemented at the AGH, it is supported by the AGH researchers, and recognized for its importance.

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The AGH promotes the two-way dialogue approach as it facilitates science discussions in a language the audience understands. The university's objective is not only to spread the knowledge gained from scientific research. Its goal is to make society aware of the value of critical thinking, which enables individuals to assess issues encountered in everyday life. The AGH's mission is to explain complex phenomena and spark curiosity and a desire to explore. The university is a place of open academic debate where scientists shed light on their research work and show ways of putting their knowledge into practice. Although the university events are for citizens of all age groups, particular focus is placed on children and adolescents. It offers activities for nursery schools, e-books for children and maintains social media channels. Events for adults are free of charge and the recordings of the events often have English subtitles. Some events are even offered in English. The university also takes part in local and international science events designed for the public. Some of these events have a long tradition dating back to 1989 and recently became part of the university's Corporate Social Responsibility Policy. Although the COVID-19 pandemic limited the activities, most of them continued online. The AGH UST Space Technology Center which is directly engaged in the Beyond UNIVERSEH project continues to broaden science communication.

While most of the activities related to popularizing science can be regarded as science communication activities, few of them fit the definition of citizen science, incorporating citizens' perspectives and knowledge into the scientific process. Nonetheless, scientists are eager to involve society in their research.

2.2 Heinrich Heine University Duesseldorf

The Heinrich Heine University Duesseldorf (HHUD) values the exchange between science and society and sees in it a benefit not only for society but also for science. It recognizes its responsibility to promote a dialogue between citizens and researchers, as a critical reflection of societal developments can only be achieved if various points of view are discussed and considered. Hence, the HHUD promotes a broad understanding of knowledge transfer closely linked to its so-called Third Mission. This third mission is complementary to the two traditional university missions of teaching and research and involves reaching out to society and engaging them in science. The HHU refers to itself as a Citizens' University (Bürgeruniversität) actively seeking an exchange between science and society.

This self-conception is reflected in its understanding of science communication and citizen science. In reference to the policy paper of the Federal Ministry of Education and Research, the Heinrich Heine University Düsseldorf defines science communication as a generally understandable, dialogue-oriented communication and transfer of science and scientific content to target groups outside the scientific community. It understands science

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communication as a two-way communication that not only aims to disseminate research results but also includes society's perspectives and ideas in the research process and thereby broadening the scientific discourse and promoting citizen involvement in research.

The Heinrich Heine University defines citizen science as the involvement of the general public, particularly citizens outside the scientific community, in science. It understands citizen science as a means of public engagement, an opening of science to society to create trust in science and acceptance of scientific findings in society. Further, it helps democratize science. Citizen Science involves citizens of all ages, genders, social and educational backgrounds and seeks to incorporate their perspectives and knowledge into the scientific process. The actual level of citizen participation, and their involvement in defining the scientific problem, collecting and analyzing the data, can vary considerably. Yet through citizens' participation, the university aims to reduce barriers between science and citizens and bring them closer together. This understanding of citizen science originates from Alan Irwin's (1995) interpretation of the term, which is widely used in scientific discussions on citizen science.

2.3 Luleå University of Technology

According to the second paragraph of the Higher Education Act of Sweden, higher education institutions should engage in mutual exchanges with the surrounding community and ensure that knowledge and expertise at the higher education institutions bring benefit to society. As a Swedish university, Luleå University of Technology obviously must consider this.

The Luleå University of Technology does not (yet) have an official definition of science communication. However, in 2021 a step towards developing one was taken, when a proposal for a strategy and action program to strengthen science communication at the university, was carried out. In that report, science communication was defined as "communication about research with others than the science community". The report also identified a broader and more inclusive definition, where science communication can target researchers in other research areas and hence create interdisciplinary collaborations.

At the Luleå University of Technology, there is an ongoing process concerning science communication. We are trying to steer from "media logic", i.e., information is distributed to a broad segment of communication receivers, for example via news items published on the university's website, to "communication logic", i.e., communication focusing on explicit content for different target groups. The latter is supposed to create more lasting relations with the target groups as well as more relevant and lasting content and information.

Science communication does play an important role at the Luleå University of Technology. The university is situated in the very north of Sweden, in a region that most of our target groups

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never have visited and know quite little about. Sharing our research results with the public is a vital task for us, contributing to our possibility to remain what we are and to grow in the future. If people know what we do, we will be able to attract more students, researchers, and eventually more research funding. But the altruistic point of view is of course the more important one; we want our research to contribute to and benefit society.

When it comes to citizen science, Luleå University of Technology has no definition but aligns with the definition presented by Heinrich Heine University Duesseldorf. We also align with the definition made by Public and Science, an independent Swedish non-profit membership organization that works to promote dialogue and openness between researchers and the public. Simply put, their definition is saying that citizen science is when the public co-creates new knowledge together with researchers somewhere in the research process.

There are indeed research projects carried out at the university that include citizen science, but there is no institutionalized definition or overall administrative function that connects the work being done. Hopefully Beyond UNIVERSEH can encourage us to mature and develop within this area.

2.4 Université Fédérale Toulouse Midi-Pyrénées

The definition of science communication and citizen science given by the Heinrich Heine University Duesseldorf corresponds in full to that of the Université Fédérale Toulouse Midi-Pyrénées. Although science communication, compared to the other scholarly missions of research, teaching, and administrative tasks, has been institutionally neglected for a long time in France, the French government has recently emphasized the necessity of a closer connection between science and society and highlighted science communication and citizen science as part of a scientist's duties. The new research programming law includes several "Science with and for Society" measures aimed at improving the interaction between citizens and researchers.

With more than 105,000 students, 8,000 scientists, and 4,000 doctoral students, Toulouse and its surrounding region display a scientific dynamism that is conducive to numerous science-society exchanges. Often associated with the aeronautics and space sector, scientific expertise is also nourished by the region's multidisciplinarity, including the exceptional interactions between the Humanities and Social Sciences (SHS) and the Sciences and Technologies (STS).

Due to the scientific ecosystem of the region, Toulouse has been able to offer science activities and share scientific knowledge with the public in a wide variety of sectors. With its slogan «Sharing Science: Towards new horizons», it was designated the European City of Science in

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2018 and thus became the only French city awarded the title. Toulouse Métropole is also the only local authority in France with a department specifically dedicated to Scientific, Technical, and Industrial Culture (DCSTI) within the General Department of Culture. The DCSTI manages and coordinates five nationally and internationally renowned institutions: La Cité de l'Espace, the Toulouse Natural History Museum, Le Quai des Savoirs, L'Envol des pionniers, and Aeroscopy. This network of institutions, attracting more than one million visitors annually, has helped shape the identity of Toulouse as a metropolis of knowledge.

Promoting the science-society continuum is of great importance to the University of Toulouse for two main reasons: it is the university's democratic mission to educate citizens and help achieve a "knowledge society" in this era of post-truth and to participate in increasing opportunities to acquire scientific information and culture and provide equal access to it, particularly at the local level.

The Université Fédérale Toulouse Midi-Pyrénées (UFT) promotes exchange between citizens and scientists, focusing on all segments of society, neglecting none. It ensures that dialogue occurs not only in Toulouse but also in the most remote rural and mountainous areas of the region. It addresses children, at various levels of the school system, from primary school pupils to university students. It also addresses adults, whether that be the staff of the university or the larger public, making sure scientists meet the public wherever they are. There are also actions addressing audiences defined as "prevented". The UFT scientists engage with audiences in psychiatric hospitals and prisons, for instance, who would otherwise not have the opportunity to engage in a dialogue with scholars through the work of the association "Les étoiles brillent pour tous".

The "science communication" side of the science-society continuum, including 350 science communication activities per year, involving 300 primary and secondary schools, with 500 trained researchers and doctoral students, is diversified and dynamic. The University of Toulouse and the Occitanie Region have also been developing the second aspect of the science-society continuum, citizen science, for several years now. Bringing research activities closer to citizens (through citizen science, open innovation, etc.) has been achieved through a particularly dense, experienced, and recognized network of regional third sector research and through the implementation of transformative mechanisms such as laboratories of ideas and transitions, Living Labs, third places, expertise platforms, and soon to come, a science shop involving students, among others.

The University of Toulouse has thus a long experience in the field of science communication and more recent experiences in citizen science projects. This is now one of the major focuses of the region's scientific actors.

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2.5 Université du Luxembourg

The University of Luxembourg is research-oriented, fostering the creation of knowledge that addresses society's challenges through interdisciplinary approaches. With more than 105,000 students, 8,000 scientists, and 4,000 doctoral students, the University of Luxembourg has more than 1,100 academic staff members who are involved in about 1,000 University research projects.

The science communication at the University of Luxembourg is mostly used in distinction to "science journalism" in the sense of "institutional science communication". It thus encompasses all communication measures taken by a scientific institution or organization vis-à-vis the public. This includes communication by the scientists themselves as well as communication by the corresponding communications department or public relations department. Currently, more and more experts are using the term "science PR" (public relations). In doing so, they are seeking to make the aspects of interest-driven communication more transparent. The term "reputation communication" is often used in this context to emphasize a critical discourse aimed at institutional science communication. In contrast, the phrase "public good-oriented science communication", which encompasses noble goals for the benefit of society, is occasionally introduced as part of the relevant terminology. Particular exchanges within the science community, e.g. those taking place at a professional conference, are still rarely attributed to science communication. Science journalism, on the other hand, is readily integrated into science communication. For decades, science journalism has rightly insisted on its markedly different approach, namely independent reporting. Accordingly, lumping it in with interest-driven, institutional science PR gives rise to a certain amount of controversy and generates criticism amongst journalists. In the context of teaching at the University of Luxembourg, we pragmatically focus on two criteria to frame the concept of science communication:

1) the group of recipients includes, at least in part, people from outside the science community and
2) the content represents, at least in part, scientific knowledge. If both criteria are met, we speak of science communication.

Citizen science at the University of Luxembourg is defined as "Research output reliant on active citizen involvement for its production", in line with the ECSA 10 Principles of Citizen Science. Therefore, citizen science is a flexible concept that can be adapted and applied in diverse situations and disciplines. Citizen science projects are supposed to actively involve citizens in scientific endeavors that generate new knowledge or understanding. Citizens may act as contributors, collaborators, or project leaders and have a meaningful role in the project. Citizen science projects have a genuine scientific outcome such as answering a research question or making recommendations for conservation actions, management decisions, or

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environmental policies. Both the professional scientists and the citizen scientists benefit from taking part in the project. Benefits may include the publication of research outputs, learning opportunities, personal enjoyment, social benefits, and satisfaction through contributing to scientific evidence e.g. by addressing local, national, and international issues, and thereby potentially influencing policy. Citizen scientists may, if they wish, participate in multiple stages of the scientific process. This may include developing the research question, designing the research method, gathering, and analyzing data, and communicating the results. Citizen science is considered a research approach like any other, with limitations and biases that should be considered in advance and controlled. However, unlike traditional research approaches, citizen science provides an opportunity for greater public engagement and the democratization of science. Citizen science project data and meta-data are made publicly available and where possible, results are published in an open-access format. Data sharing may occur during or after the project unless there are security or privacy concerns that prevent this. At the University of Luxembourg, citizen scientists are acknowledged in project results and publications, programs are evaluated for their scientific output, data quality, participant experience, and wider societal or policy impact. The leaders of citizen science projects take into consideration legal and ethical issues surrounding copyright, intellectual property, data sharing agreements, confidentiality, attribution, and the environmental impact of any activities.

3 Institutional Structures to Promote Science Communication & Citizen Science Activities

Science communication, as well as citizen science activities, take place in certain institutional settings, which influence their development and implementation. When looking at best practice examples in both fields, it is, therefore, necessary to consider these preconditions. This chapter focuses on the institutional structures science communicators and citizen science coordinators encounter at their respective institutions when engaging with the public. These structures, often linked to certain strategies that universities follow to support and promote such activities, are also reflected in this chapter.

3.1 AGH University of Science and Technology

To promote and democratize science, the AGH UST has established the Centre for Communication and Marketing. The center coordinates and communicates activities taking place at the university level and initiates university participation in local or national events. It is

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responsible for the university's social media channels. At the AGH Space Technology Centre, an expert communicates and disseminates the center's activities.

3.2 Heinrich Heine University Duesseldorf

To foster knowledge transfer and dialogue with citizens, the university has established a department called Citizens' University. Alternative: The Citizens' University encourages all university members to engage in science communication activities and discussions. It promotes involving citizens in the scientific process and service-learning offers. It offers funding for science communication and citizen science activities as well as consultation services and training for researchers and students interested in conducting science communication and citizen science activities.

In the field of science communication, the Citizens' University offers ad hoc funding for single projects. Lecturers of all university levels can apply for funds of up to 1.000 €. Application procedures are simple. In addition, students working on scientific projects monitored by lecturers may also apply for funding. The Citizens' University funds research activities with citizen participation as well. As of 2019 citizen science activities are funded yearly with a sum of up to 140.000 €. In cooperation with external partners, socially related teaching formats such as service-learning, science communication, research-based learning, and innovative internships are also supported by the Citizens' University. These teaching activities are designed to encourage student civic engagement and help students develop personal values. In close cooperation with external partners, they also help students with their later transition into the academic labor market. The maximum amount of funding per project encompasses 25.000 €.

The Citizens' University organizes a variety of events to promote an exchange between science and society. These events target citizens of all ages, educational backgrounds, incomes, nationalities, languages, and mobility that live or work in or close to Duesseldorf. These diverse target groups are taken into consideration when planning activities, topics of discussion, and communication channels. Activities offered by the Citizens' University include exhibitions and dialogue forums among others. Due to the active support of the Heinrich Heine University, it has become especially strong in the areas of knowledge transfer and societal engagement.

The Citizens' University program advisory board awards events and activities that meet their criteria with their quality seal "Citizens' University". Criteria for the seal include a topic relevant to society and corresponding to the researcher's expertise, a format appropriate for the target group, and innovative elements (e.g. ted-voting, debate). The program advisory board is composed of members of the Department of Citizens' University, the Press and

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Communication Unit, the Events and Marketing Service Unit, the *Haus der Universität,* and a representative of each of the five university faculties. The board supports the Citizens' University in its strategic development, creates the Citizens' University program, supports the initiation of networks, and forms project groups to help implement the strategic goals. The Citizens' University is supported by an advisory round table, which functions as a discussion forum.

The Heinrich Heine University Duesseldorf also offers its researchers and students who are conducting science communication and citizen science activities a venue for their science events. The so-called Haus der Universität, located in the city center, hosts a variety of science events for the urban community to promote an exchange between scientists and citizens. A blog, established by the Citizens' University, offers students and researchers a science communication platform in which they can present their research, exchange ideas and thoughts.

The Heinrich Heine University's researchers and staff consider it their duty and responsibility to contribute their expertise and research to help overcome the current societal challenges. The Heinrich Heine University, therefore, offers consultative science communication involving not only an active exchange among decision-makers, institutions, political and economic organizations as well as the civil society but also consulting of all of the above. Many scientists of the University and their research organizations offer important contributions to the present social discourse and decision-making processes. They are actively supported by the university management, in particular by the Vice President for International Relations and Science Communication who has been responsible for consultative science communication and its strategic development at the Heinrich Heine University since 2019.

3.3 Luleå University of Technology

The main responsibility for science communication lies with the Department of Communication and Collaboration. The department is responsible for external communication, student recruitment, and strategic initiatives addressing collaborations between the university, the public, companies, and local and regional authorities. The department coordinates outreach events and runs the university's official social media channels. The department is also in charge of the university's website and works operationally with content for web pages and press releases. There is no specific institutional structure for citizen science.

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3.4 Université Fédérale Toulouse Midi-Pyrénées

Since 2010, the Université Fédérale Toulouse-Midi-Pyrénées has had a service dedicated to science communication and citizen science, although this sector is only now being developed. It is called the Direction de la Diffusion de la Culture des Sciences et des Techniques (DCST) and is composed of a staff of 10 persons with an administrative director and a scientific adviser. The DCST does not provide funding for individual projects but organizes events and creates structures to foster dialogue between science and society. Examples of such festive events include the European Night of Researchers, Ma Thèse en 180 secondes, and the Science Festival Week. Further activities include convivial encounters between scientists and citizens as *les rencontres Exploreur*, and *les Curieuses visites curieuses*, innovative pedagogical activities with school children and students between the ages of 6 and 25 as the ASTEP-scientific and technical workshops in primary schools, and the Scientific Conference of Children. It has also launched a science communication online magazine, containing articles, portraits, podcasts, and videos.

The situation in Toulouse is slightly peculiar as the Université Fédérale brings together 31 higher education and research institutions and organizations. The science-society dialogue is carried out just as much through actions specific to one of the UT member institutions as through collective actions that are mainly coordinated by the DCST service in collaboration with other academic and non-academic structures.

Most of the campuses have their own science communication actions. Most have specific services, with administrative directors and, in some cases, vice-presidents in charge of science communication. This means that, in addition to the collective actions organized by the Université Fédérale, each component organizes its own actions, more specific to the specialty of the component. For instance, the Humanities and Social Sciences campus (Campus Jean Jaurès) has a service dedicated to science communication, a vice-president, and a wide range of actions. The Science, Technology, Engineering, and Health campus (Campus Paul Sabatier) has a dedicated service as well. Actions are also organized by TBS, ISAE-Supaéro, and INP.

3.5 Université du Luxembourg

In 2018 the University of Luxembourg launched the project DESCOM, the Doctoral Education in Science Communication, which aims to support interactions between academia and the public by providing different modes of training in science communication. The project was supported by the Fonds National de la Recherche, Luxembourg (FNR) and the DSSE. The DESCOM team not only promotes and organizes outreach activities but also provides formal science communication training for doctoral candidates of Luxembourg in the form of a

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transferable skills course as well as through internships at one of the several partners of DESCOM. Furthermore, DESCOM developed a pocket guide to provide support as well as theoretical and practical knowledge on science communication to interested audiences. The growing network of partners indicates how important science communication skills are in academia and the industry. Thus, DESCOM strives to improve these skills in doctoral candidates and thereby increase their visibility and employability in the job market of Luxembourg.

The objectives of DESCOM are to a) train young scientists in science communication, b) support and organize outreach activities, c) foster networking and cooperation of the different research institutes involved, and d) increase the employability of doctoral candidates. DESCOM offers are open to all doctoral candidates in Luxembourg to promote interdisciplinarity, networking, and cooperation. As science communication is becoming more and more important in today's society, with DESCOM the university hopes to foster a culture of science communication.

DESCOM provides education in science communication to young scientists to sustainably foster the dialogue between researchers and the greater public or other stakeholders. One science communication example is a course open to the staff members, students, and researchers of all disciplines of the University of Luxembourg. Another example is an introductory course, which gives doctoral candidates an understanding of the basic concepts of science communication. The formal training offers an introduction to the organizational structures of science communication as well as essential communication tools (e.g. print, social media, or videos). The course content is interactive, the students work in groups and are for example asked to write a press release and even found a new research center. Individually designed assignments are prepared in groups in between the two block courses. Deepened learning skills and further ECTS points can be acquired in outreach activities or science communication internships at one of DESCOM's partner institutes. Those internships deepen the participants learning skills in science communication. Applications are possible year-round. Further information about the internships can be found on the DESCOM website.

As the main aim of DESCOM is to support interactions between academia and the public, they designed several outreach activities on different topics, targeting different audiences and using different means of communication:

Science & Research Writing Competition: All scientists and researchers as well as anyone working in research or innovation in Luxembourg are invited to participate in this popular science writing competition. The competition is organized in collaboration with science.lu. For more information about the winning articles please visit this news article.

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Cancer Quiz: To educate the public about cancer, doctoral candidates developed a cancer quiz on Kahoot in several languages. You can challenge yourself as well in the English, French, or German quiz.

3MT Video competition: DESCOM also supported the 3MT video competition organized by LuxDoc in which scientists competed against each other in a three-minute video about their research.

Cancer quiz on Kahoot
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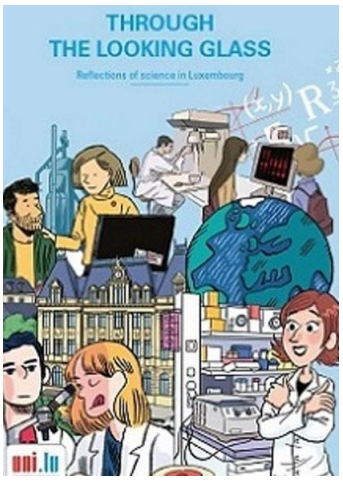

Book cover of the comic LUX:plorations
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Science Comics: DESCOM members developed science comics about research in Luxembourg. The two-paged stories about different fields of research were developed by doctoral candidates in collaboration with artists. LUX:plorations is the newest comic and can be downloaded in English, French, German, or Luxembourgish. Here you can also find more information about the people involved. Volume 2 is even available in Portuguese! The first comic was published in 2019.

Information booth: DESCOM also supported the information booth about the link between pesticides and cancer during the Lëtz go Gold charity run, which was organized in collaboration with the Luxembourg Institute of Health (LIH).

Luxembourg's Science Slam 2021: DESCOM also supported the Science Slam organized by LuxDoc.

4 Best Practice Examples in the Field of Science Communication

This chapter provides best practice examples in the field of science communication. Best practices are cases that are especially innovative and have demonstrated success. Most of the examples are being or were implemented at UNIVERSEH's partner universities. Others were conducted in the universities' respective countries and chosen for their innovative character and/or focus on space-related topics. As the UNIVERSEH Alliance focuses on space education, the majority of the examples are in the domain of space science. Further science communication activities in the field of space science can be found in Annex 1.

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This chapter aims to share experiences with scientists who are actively engaged in or planning to engage in science communication activities with the public. It reflects a variety of science communication formats and covers a wide range of objectives and audiences. The examples all follow the same structure and include a description of the activity, its objectives, channels, and tools used when implementing the project, target audience, outputs and impacts, successes and challenges, and recommendations for reimplementing the activity.

4.1 AGH University of Science and Technology/Poland

4.1.1 AGH UST Junior

Short description of the activity

AGH Junior is an educational university project coordinated by the Centre for Communication and Marketing for preschool and primary school-aged children. Its goal is to show that complex physical and chemical phenomena, knowledge of mechanical and electronic engineering, processes taking place in the natural environment, or problems related to the production, testing, and use of materials are not only the domain of our research laboratories. These seemingly difficult subjects can become a real passion for juniors.

Logo of the AGH Junior
© AGH University of Science and Technology, AGH Junior

Main objectives

The main objective of the AGH Junior initiative is to relate science in a way that encourages children to learn, ask questions, develop a passion for science and inspire them to choose a career in the sciences.

Channels & tools

There are 3 channels:

- AGH Junior Academy
- Series of articles and films
- Series of books written by AGH scientists

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Target audience

AGH Junior Academy is a series of events for children eight through twelve years of age. The course program was developed by university teachers and adopted for two specific age groups. The activities take place at the university and include lectures, exercises, and labs conducted by university researchers. A participation fee of 500 zł (circa 120 €) is required per academic year. Unfortunately, the academy's activities have been interrupted due to the COVID-19 pandemic.

At the AGH Junior Academy children are allowed to do simple experiments
© AGH University of Science and Technology, AGH Junior

Output & impact

Since two of the main communication channels focus on one-way communication (books, articles, and films), they can be considered tangible outputs of this project. The events lead to an increased interest in science-related topics among children as well as a better understanding of the discussed topics. Parents also became aware of the value of science and the possibilities an education in science has to offer. The events were also a great source of pleasure for children which can be seen as a positive output.

Successes & challenges

The success of the project lies in activating researchers to popularize science by reaching out and sharing scientific knowledge with children and adolescents all over the country. The books sold online and published on our website also attributed to its success, and last but not least, the direct contact with the participating children and their parents.

The AGH Junior book covers
© AGH University of Science and Technology, AGH Junior

The main challenge is finding individuals interested and talented in communicating science.

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AGH

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LULEÅ UNIVERSITY OF TECHNOLOGY

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What to consider when reimplementing the described activity

As the AGH Junior project is complex, each of the events that take place at the AGH needs to be individually analyzed. Essential for the activity is however scientists' capability of explaining complex issues to children in a simple way.

4.1.2 AGH SCIENCE Meetings

Short description of the activity

The AGH SCIENCE Meetings are a series of short popular science presentations and discussions with scientists and specialists. In these meetings, scientists present their research in a manner the audience understands and explain the importance of their work. The meetings are open to the public. Like AGH Junior, the project is an initiative of the university's Centre for Communication and Marketing.

Main objectives

Science is developing rapidly as are the fields of specialization in science. Specialists often explain scientific innovations and findings in a technical language the public does not understand. As everyone benefits from the skills and knowledge of science, a public understanding of that knowledge profits science as well as the public. The AGH's Science Meetings objective is to promote this understanding and make society aware of the value of science and critical thinking that help us develop decision-making capabilities to solve everyday problems. The AGH's mission is to spread knowledge to benefit society and improve people's lives.

Posters informing about the AGH Science Meetings
© AGH University of Science and Technology, AGH Science Meetings

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Channels & tools

Two main instruments are used to implement the objectives:

- Meetings: During the academic year meetings are held on the AGH UST campus usually once a month in the afternoon. A single event consists of two lectures, each of them lasting 30 minutes. Following the lecture, the speakers take 15 minutes to answer questions from the audience. The meetings last one and a half hours.
- Recordings of meetings: Recordings of the events can be viewed on the AGH YouTube channel. During the pandemic, this tool has become an important channel of communication, as live meetings were strongly restricted or even impossible.

The Space Technology Centre also organizes webinars with international experts in space science and space-related fields. These online presentations allow viewers to submit comments and questions which are answered following the lecture.

Target audience

The events are open to the public and free of charge.

Output & impact

Since the project is open to the public and participation is free of charge, the project has a social function that should not be underestimated. It offers both the speakers and participants the opportunity to meet and discuss relevant subjects, present their work and research, express their opinions and gain experience. As the recordings of the AGH Science Meetings are accessible on the YouTube channel, it contributes to the university's outreach mission.

Successes & challenges

The AGH Science Meetings were intended to be conducted live at the AGH. Due to the Covid-19 pandemic, they were continued online which proved to be a great success. The challenge now is to enliven the meetings to keep public attention and interest and attract a broader audience. A notable and unexpected success of the meetings was the recognition of Dr. Anna Sowidzal by the Science in Poland Portal, a platform run by the Polish Ministry of Education and Science for her lecture on geothermal energy, held as part of the AGH Science Meetings. An article based on the lecture has been published.

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What to consider when reimplementing the described activity

Despite good intentions, scientists are not always able to step out of their academic role when speaking to non-professionals about science. As communication skills are a key factor for the success of the project, intensified cooperation between the scientific community and communication specialists and training in the field of science communication are strongly advised. These skills can help scientists arouse public interest in science and help them reach a broader audience. Dialogue and respect for mutual goals are the base for successful cooperation between scientists and society.

4.2 Heinrich Heine University Duesseldorf/Germany

4.2.1 denXte

Short description of the activity

„denXte“ is an innovative lecture series initiated by Prof. Dr. Markus Schrenk at the Institute of Philosophy and run together with a team of postdocs and students: Dr. Amrei Bahr, Julia Frese, Dr. David Löwenstein, David Niemann, Christoph Sapp, and Berit Weiß. The series, which began in September 2019, offers approximately six evening lectures yearly at the *Haus der Universität*, a university event location in the city center of Duesseldorf. The project is funded by the Citizens' University and the HHU's Faculty of Arts.

Logo of denXte
© HHU Duesseldorf, denXte

In this interactive lecture series, philosophical thought experiments are conducted together with the participants. A thought experiment is a mental exercise in which a hypothesis is posed and the potential consequences are explored. Each lecture, given by a renowned philosopher, begins with a short introduction to a socially and scientifically relevant question. The participants have the opportunity to comment on and discuss this specific philosophical question and also to vote through a smartphone application. The guest philosopher then addresses the respective issue further and presents important viewpoints from the central philosophical debate. The lecture is followed by a discussion during which the participants have the opportunity to ask further questions and put forward their arguments. Finally, the participants are asked once again to express their opinion on the matter in form of a vote for or against the issue via the smartphone app. The results of both surveys are then compared to determine if the participant's assessment changed or remained the same within the course

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of the experiment. Following the event, participants are invited to take part in an informal discussion similar to a science café with academic philosophers.

During the COVID-19 pandemic, the lecture series was offered as an online livestream on denXte's YouTube channel and via Zoom. In addition, the lectures were recorded and edited in a way that allowed the participants to re-enact the thought experiments. These videos have been made accessible on the project's website. In response to the long ongoing pandemic, the denXte team also established the online format denXte-eXtra. denXte-eXtra is similar to denXte but in video form. The short videos present different viewpoints on a philosophical question. The viewers can contribute their thoughts on the subject by using the comment section of the website and have access to blog entries from experts in the field. They are then asked to express their own opinion by voting for or against the matter. Both denXte and denXte-eXtra allow the public to take part in philosophical debates asynchronously without having to participate in an in-person session or livestream.

Main objectives

The thought experiment's low theoretical complexity and narrative structure allow non-professional philosophers to get an insight into current academic philosophical debates. The goal of the thought experiment is to make complex decision-making processes come alive by broadening the participants' perspectives. On the one hand, it offers the interested public insight into the current research. On the other hand, it offers philosophers the opportunity to analyze the intuitions of the participants and include them in meta-philosophical questions regarding thought experiments.

Channels & tools

Various social media channels such as Facebook, Instagram, and Twitter are used to promote the project. Issue-specific recipients are addressed by a target group-specific approach, for example by posting information in social media groups relevant to the recipients. Additionally, social media channels are used for the accompanying livestream discussion. The events are streamed on YouTube and recorded. denXte's website provides information on its activities and events. The recordings of the livestreams and the edited version of the videos, which allow participants to re-enact the thought experiments, can also be found here. Further tools implemented in the project include the smartphone voting tool ARSnova, the moderated comment section of the website, denXte's blogposts, podcast, and a newsletter. denXte uses print media such as postcards and posters to promote their project, too. Also, a special issue of the university's magazine on the ethics of organ donation was published by denXte.

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Target audience

denXte, as well as denXte-eXtra, is open to the general public. It targets the philosophically interested public as well as individuals interested in the specific topic of discussion, especially in the city of Duesseldorf. The online events additionally allow for regionally diverse participation. The lecture series addresses individuals of high school age and beyond. To reach all target groups diverse communication channels are used by the team. The evening events are free of charge to facilitate participation in the thought experiment.

Participants voting during a lecture
© HHU Duesseldorf, denXte

Output & impact

Through its innovative character and multimedia use, denXte and denXte-eXtra have evoked public interest in philosophy, thereby bringing philosophical questions and theories to non-professional philosophers. Through social media channels, its website, the ARSnova voting tool, its newsletter, and conventional print media the project has managed to motivate citizens of various age groups to participate in philosophical discussions. This experimental and interactive form of science communication has offered citizens a low-threshold entry into philosophical research and allowed for interaction with citizens on equal terms. These events and discussions have also led to the production of a series of videos on philosophical debates, all publicly accessible, designed as an outreach to the public to take part in the discussion. Participation in the discussion concerning organ donation was so great that the Heinrich Heine University Magazine published a special issue devoted to the intensely discussed topic. Furthermore, seminars concerning science communication within the context of the denXte concept have brought about creative student projects. Here are a few examples: Students have created short explanatory videos on thought experiments, which are to be integrated into denXte-eXtra. They have developed ideas to make thought experiments more dialogue-oriented. Students will also create podcast episodes dealing with philosophical questions that are of special relevance to citizens. These are to be fed into a new segment of denXte, called “mitgedacht”, and will be launched in autumn 2022.

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Successes & challenges

denXte has been successful in generating lively discussions and thereby achieving and maintaining its popularity. It won the Communicator Award 2022 of the German Research Foundation and Stifterverband for its innovative and forward-looking science communication. It has attracted a wide range of participants from high school, college, and university students, to middle-aged and senior citizens. The first in-person sessions before the pandemic were well attended. Participation increased steadily and with time, the event location reached its capacity limit. The project team received a great deal of positive feedback during and following the sessions. In response to the COVID-19 pandemic and social distancing measures, the team developed a new format called denXte-eXtra, which also quickly gained popularity. Its success is evident when observing the lively online discussions. By integrating denXte in the Department of Philosophy's teachings, students' science communication skills have been strengthened which is reflected in their creative output as mentioned above (explanatory videos, new concepts on thought experiments, podcasts, etc.).

Lecture by Thomas Grundmann on the topic of Fake News
© HHU Duesseldorf, denXte

One of the greatest challenges facing denXte is securing a long-term financial source, which is necessary to ensure the continuance of the lecture course. The existing funds for denXte and other science communication activities are limited. Therefore, it is not clear if and how the lecture course can be continued once these funds are depleted. In addition, although this type of science communication requires a lot of human resources, only the team leader has a permanent university contract. Apart from organizing the lectures, particularly time-consuming is the production of the videos and moderating the online discussions. The latter has become especially evident in discussions concerning controversial topics such as organ donation. Although these topics are of great interest to the public, they can become very complex and easily spin out of control. Intense discussions also require good moderation, which is not only challenging but can exceed boundaries. Unfortunately, the COVID-19 pandemic and the shift of the lecture series to the online livestream have resulted in a decline in participants. This decline could be attributed to the prevailing home office situation with its constant daily online conference meetings etc. Little ambition remains for more online discussion following a full workday. It

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could also be attributed to the fact that livestreams do not generate the same kind of event character that live events do and are therefore less attractive. A further challenge lies in implementing the innovative ideas developed by HHU students. As adequate online tools are lacking, expertise is needed to develop the required infrastructure.

What to consider when reimplementing the described activity

Although science communication activities are increasingly required, funding is limited, yet essential for the success of the project. Finding a grantor or suitable funding organization for a science communication project is therefore of utmost importance. To receive funding for a science communication activity, the project must often be integrated into research and teaching, which should be taken into consideration when conceptualizing the activity. Based on the project group's experiences the use of a wide range of communication channels as well as a target-group-specific approach proved to be important working tools. Posting project information in issue-specific groups helped project members reach the respective target groups. Careful event scheduling is also a crucial factor when planning an activity. In times of social distancing and increased online events, competition with other event organizers needs to be avoided. Moderating online discussions and commentaries, responding to social media posts, blog posts, etc. is not only very challenging but extremely time-consuming. The project's team, therefore, encourages project planners to allow for sufficient and permanent human resources.

4.2.2 aero|race Lab

Short description of the activity

The aero|race Lab is the FH Aachen - University of Applied Sciences' mobile school laboratory. The lab's team is composed of 12 students of the Faculty of Aerospace Engineering and its supervising Professor Frank Janser. Members of the team travel with their mobile lab truck to high schools where they speak of their studies and together with students conduct experiments and present application examples in the field of fluid mechanics and aerodynamics. For example, students use a driving simulator to calculate, test, and analyze the changes made to a racing car to improve its racing time. Apart from visiting schools, aerolrace Lab actively presents its project, the University, and especially the

Logo of aero|race Lab
© FH Aachen, Tina Sankul aero|race Lab

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Faculty of Aerospace Engineering at trade shows and other information events and offers single information events as well to give high school students an exclusive insight into the project.

The aero|race Lab was introduced in the summer of 2018 and is funded by the European Regional Development Fund EFRE and the initiative ANTalive. The lab's team also cooperates closely with the University's Formula Student Team, Aixtreme Racing developing the structure of the mobile laboratory as well as the experiments.

Main objectives

The main objective of the aero|race Lab is to spark high school students' interest in the STEM fields, especially in vehicle engineering, propulsion technology, and aerospace as well as encourage them to pursue a career in the field of science. During its one-day visit to respective high schools, the Lab's team seeks to broaden the students' understanding of physical principles, especially in the field of aerospace. By conducting practical experiments with the students and offering them application examples, the team can pass their knowledge on in a very interesting way.

Mobile lab truck of the aero|race Lab
© FH Aachen, Tina Sankul aero|race Lab

Channels & tools

The aero|race Lab provides information concerning its mobile student lab on its website. To reach its target audience of high school students, the lab actively promotes its project on Instagram and Facebook where it presents new projects, reports on past events, and shares tech information. The Lab also produces YouTube videos as a channel to promote its work.

Target audience

First and foremost the aero|race Lab targets high school students. As these students can best be reached through their schools and respective science teachers, they are very important partners for the project.

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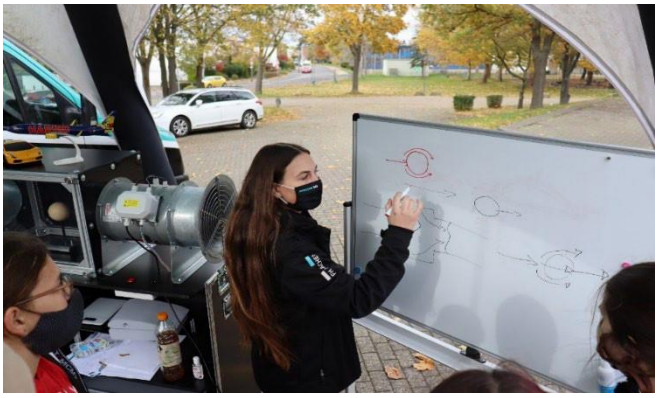
Output & impact

Group of students conducting experiments
© FH Aachen, Tina Sankul aero|race Lab

To monitor the effect aero|race Lab has on the students, the participants are asked to take part in a survey following the lab. Results of these surveys show that the lab has been successful in arousing interest in a career in the field of engineering. It also shows that the aero|race Lab's greatest strength lies in bringing theory and practice together, demonstrating the link between engineering and everyday life. The Lab's experiments and illustrative examples in the area of motorsport racing help students gain insight into the work of an engineer/mechanical engineer. Through independent learning in the lab, students can acquire their knowledge and apply the knowledge they have gained to their lab work. It also helps them understand the mathematical formulas they have discussed in class and sparks interest in engineering. By taking part in the aero|race Lab students become involved in science without prior knowledge of engineering.

Successes & challenges

The aero|race Lab's team gives students the opportunity to conduct experiments in physics, which are often much too costly and complex for high school laboratories. The experiments and application examples are designed to ensure that all students regardless of their prior knowledge leave the lab with new perceptions of engineering and mechanics. Additionally, the Lab's team helps students visualize the links between mathematics and physics and understand their practical application in everyday life. A challenge for the aero|race Lab team lies in finding ways to address and inspire those students who attend the lab but have little interest in the sciences.



aero|race Lab team member teaching students
© FH Aachen, Tina Sankul aero|race Lab

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What to consider when reimplementing the described activity

To ensure the success of a lab and convey enthusiasm to the students, a well-organized, passionate team of ongoing engineers is essential. As the lab must constantly adjust to the needs of the participating schools and their students, it is important to design an elaborate lab concept that leaves room for adjustment and change. It has proven helpful to divide the students into small groups. This makes the experiment procedure more efficient and allows the team members ample time to answer questions and give more in-depth information. The aerolrace Lab's team also recommends preparing four to five experimental stations through which the individual groups can pass consecutively.

4.3 Luleå University of Technology/Sweden

4.3.1 Vetenskapens hus (The House of Science)

Short description of the activity

Vetenskapens hus is both an actual building in the city center of Luleå, and an arena for science communication. The venue opened in 2014 and is run by three partners: the Royal Swedish Academy of Engineering Science, the mining company LKAB, and the Luleå University of Technology. The university has a coordinator for Vetenskapens hus, who is assisted by a board and a program council. The program council consists of representatives from companies, the municipality, and the university and their task is to suggest thematic areas for events, seminars, and lectures targeting a non-academic audience.

Vetenskapens hus during a lecture for the public about democracy
© LTU Sweden, Vetenskapens hus

Main objectives

The primary objective of Vetenskapens hus is to reach out to the general public with the university's research, framed in a popular science way. A secondary objective is to reach out to companies, authorities, and research funding agencies. The aim is to use science as an

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enrichment for society, to create a democratic platform where facts and research results are in focus.

Channels & tools

The most common channel, in this case, is of course the venue itself, in Luleå. That is where most of the lectures and events take place. But also, some lectures – or different ones – take place at the university's three other campuses (in the cities of Piteå, Skellefteå, and Kiruna). Some of the events are live-streamed and most of the events are recorded and published on the university's YouTube channel. To reach our audiences and target groups before an event, we promote the events on our website, on our social media channels, on digital information displays all around our campuses, and sometimes in the local newspapers.

Target audience

The target audience for Vetenskapens hus differs depending on the event. But the non-academic characteristic is shared by all target groups, the aim is to attract the public whether it means teenagers, students, or elderly people. Another important target group is companies, not the least regional SMEs.

Output & impact

Since Vetenskapens hus is not one activity, it is hard to extract output and impacts. An impact we want to achieve though is that whoever is participating in the events, whoever is listening to a lecture – will feel more attached to our university and that the thresholds for learning from science are lowered.

Luleå campus is not located in the city center of Luleå, therefore, Vetenskapens hus gives the city a glimpse of what we are and what we are doing. Another aspect that should not be underestimated, is the impact from the researcher's point of view. For some researchers, meeting with the public can give valuable input and not the least – energy – to the otherwise quite conform research workdays.

Successes & challenges

We should be honest – not all events and lectures are successful. But some are, for sure. The pandemic years of 2020 and 2021, made us rethink and realize that in the end, a much larger

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audience needs to be reached. Digital popular science lectures were seen by thousands of people all over the country. From our experience, lectures on “nerdy” subjects are often well attended. For example, the university had a series of lectures about cross-country skiing and ski waxing that turned out to be a great success. Also, a digital popular science lecture on the darknet attracted a lot of attendees from outside of Luleå.

One of the biggest challenges we have experienced is the difficulty to make researchers understand the concept of popular science. Their lectures are often too long, too detailed, and too complicated and that creates an insecure audience (“was I not supposed to understand this?”). A huge challenge is therefore to identify researchers that can popularize science, preferably those who can turn science into infotainment.

What to consider when reimplementing the described activity

Some simple advice:

- Spend some time identifying where you can find your target groups. The more precise the target group is, the easier it is to reach them (via social media channels or customer relationship management systems), and the better the result.
- Can the lecture be live-streamed? What you lose in eye contact with the audience, you might gain with a broader outreach. Also, we have noticed that young adults and teenagers, may be more likely to attend digitally than on-site.
- Educate your researchers! It is hard to speak easily and interestingly about something you know everything about to non-scholars. If a researcher manages to evoke enthusiasm in the audience, the value of the interaction increases.
- How do you get the audience to interact with the lecturer? This can sometimes be the key to a successful result.

4.3.2 Tech for Youth

Short description of the activity

Tech for Youth was an activity carried out by the Luleå University of Technology, sponsored by Facebook (Facebook, now Meta, built its first European data center in Luleå. Three giant server rooms are situated just a stone’s throw away from campus). Within the framework of Tech for Youth, four activities were performed: the Preschool Challenge, Remote experiments, Ask a researcher, and the Technology challenge.

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Preschool challenge. Kids in preschool were asked to send in the best examples of their work with the STEM subjects. The project group chose the winners, and the winners received a box with experimental building material.

Remote experiments. A chemistry experiment for children in the first and second grades. This was an excellent example of how the pandemic forced us to think outside the box. Instead of inviting classes to a chemistry lab at the university, the experiments were done via Zoom, hosted by one of our university students. Most of the ingredients of the experiments could be found in ordinary kitchens, encouraging the children to try them at home. An important part of the experiment was interaction with the kids. As the experiment went along, the student continually asked questions: “What do you think will happen next? What does this smell like? How much should I pour?”.

Ask a researcher. We let high school classes e-mail us questions about anything. We then put them in touch with a researcher who could answer their questions. Aims at high school teenagers.

Technology challenge: Target group was eighth-graders. The university made boxes that were sent to participating classes. Inside the box were tricky questions that were to be solved within a specific timespan, and all the answers were to be converted into binary numbers. The winning class received a price: a whole day spent at the university, meeting researchers and visiting research labs.

A film was also made within the framework of Tech for Youth. The purpose of the film was to inspire girls specifically, to seek a path in the STEM field and/or in the realm of technology.

Main objectives

The primary objective of Tech for Youth is to get children and young people interested in STEM subjects. The secondary objective is to encourage gender equality, to broaden the conception of what you can study and what profession you can eventually choose for the future. Traditionally, girls and women are underrepresented in the field of civil engineering, a fact that we aim to change at the Luleå University of Technology. A third important objective is to reach out with our research and inspire young people to have fun with STEM subjects.

Channels & tools

The target groups are reached via the university’s website and invitations are sent directly to schools and teachers. Because of the pandemic, all four parts of Tech for Youth took place digitally.

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Target audience

The target audiences are children and adolescents between the ages of 4 and 18, living in the Norrbotten region where the Luleå University of Technology is situated. Additionally, there is an inclusive aspect – the activities are especially aimed at girls and young women.

Output & impact

According to the teachers whose classes were involved in Tech for Youth, the activities had a great impact on the participating children. They had a great time doing the assignments and we managed to create an important first encounter with them, hopefully, the beginning of a long relationship and if not with our university, at least with some institution of higher education. The demand was larger than Tech for Youth could handle. We had to say no to several classes that wanted to join the events. This was a pleasant problem and the classes are now in line for a future round of the events. The researchers involved were also pleased with the results. For some researchers, outreach is a great way of refilling the energy depot – it is a lot of fun!

Successes & challenges

Tech for Youth started during the pandemic, forcing us to create digital events instead of face-to-face meetings. At first, we found it to be an enormous challenge, but it soon turned into a success. For example, the remote experiments may not have been as popular if the classes had to come to a lab at the university. It probably would have been hard for them to find the time to leave school, travel to campus, watch the experiment, and travel back to school. Logging in to Zoom from the classroom, and joining the experiment for 30 minutes, was much more achievable.

A challenge we ran into was our lack of activities, i.e., if a group of children wanted more after a finished activity, we did not have anything more to offer. Nothing of: “You liked this? Well, we have more!”. This is of course bad from a relationship point of view if we want to keep the children interested and challenge them even further. In the future, we need to step up and offer them more possibilities. In retrospect, we also wish we had more initiatives for teachers during the Tech for Youth activities; a program to help and inspire them to develop the STEM subjects. If we develop the Tech for Youth concept in the future, this is absolutely one aspect we need to consider. Another tricky thing we encountered was the involvement of the youngest children in pre-school. It takes a lot of specialized knowledge to reach out to young children and it is hard to know if you are successful.

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What to consider when reimplementing the described activity

Spend some time to find the researcher's gems! Children and teenagers are extremely important target groups since they are the future of our universities. Most researchers know that and are willing to put in the extra work to reach out to them. Another aspect that may need some thought is the subjects you chose for the execution of the project and the proper type of event to present that subject. What STEM subjects should be highlighted, why, and how?

4.4 Université Fédérale Toulouse Midi-Pyrénées/France

4.4.1 Children's Scientific Conference

Short description of the activity

Since 2009, the University of Toulouse, in partnership with the Cité de l'Espace (the Toulouse Space Museum), organizes the Congrès scientifique des enfants (Children's Scientific Conference). Each year, in May, the conference takes place at the Cité de l'Espace, involving over 200 children attending the last two years of elementary school and the first year of junior high school (4th through 6th grade). During the COVID-19 pandemic, the conference was held online. After an opening by officials of the university, the Cité de l'Espace, and the funding partners, a French astronaut or scientist involved in space science gives a keynote lecture in dialogue with the children. Following the lecture, the children meet in panels where they present their research regarding the year's theme. The event is designed as a science conference and follows the general procedure of a science conference with nametags, panels, posters, a keynote speaker, and a conference briefcase including goodies, a conference program, games, and an evaluation form. The theme of the conference is always related to space or astronomy. Among the themes chosen for the past conferences were "Imagine your School on the Moon", "Exploring the Solar System", "The Moon", "Men and Women in Space", "Terrestrial and Extra-terrestrial Life", "The Solar System", "the Space Conquest". Each class must present two posters and two oral

Children's Scientific Conference
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presentations. In the past 12 years, the keynote speakers have included astronauts such as Léopold Eyharts, Claudie Haigneré, Philippe Perrin, Michel Tognini, and Jean-Jacques Favier, as well as engineers and space project managers.

Main objectives

The aim is to give children a “taste” for science and encourage them to pursue vocations in the field of science. Although other science communication activities such as visits to research laboratories or encounters with scientists have the same objective, the opportunity to participate in a science conference, an important activity in scholarly careers, is seldom offered to children. This is the original aspect of the project. The experience is extremely formative as it introduces children to documentary research, helps them develop communication skills, competencies, and methods to acquire knowledge not only in the field of space but in all fields of scientific research.

Children’s Scientific Conference
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Channels & tools

The three main partners involved in the Children’s Scientific Conference are the Cité de l’Espace, the Académie de Toulouse, and the University of Toulouse. The Académie de Toulouse selects the classes that are to participate in the conference and the University of Toulouse selects the Ph.D. students that will help the children conduct their research and organize their presentations. The Ph.D. students meet with the participating classes several times during the school year, helping the children select topics pertaining to the annual theme, assisting them with their research, and with preparing their posters and oral presentations. This activity is part of the Ph.D. students’ training, which includes specific training in science communication before they meet their classes.

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Target audience

The target audience is children attending the last two years of elementary school and the first year of junior high school (grades 4 through 6).

Output & impact

Beyond sparking children's interest in science and encouraging them to go on to higher education and pursue a scientific career, the conference enables children to meet and exchange ideas. The participating classes, specifically chosen by the Académie de Toulouse, represent a mixture of social classes including children from the underprivileged neighborhoods as well as those from the more affluent areas of Toulouse and the rural areas of the region.

Successes & challenges

The evaluation of the activity, conducted every year, shows that the event profits especially children from the least affluent neighborhoods. They gain self-confidence when they see that the presentations given by the children from more privileged schools are no different from their own. The very formal organization of the conference and the general staging of the event also trigger pride among the children, whatever their social origins. The audience's reception of their presentations, the applause, compliments, and questions, make them feel valued.

The success of the conference is undeniable as can be seen in its progressive expansion. Initially involving only schools in Toulouse, the conference expanded to the neighboring suburban towns and then to the whole region, before reaching a national dimension in 2017. At that time, the project also involved the Planetarium of Vaulx-en Velin, the University of Lyon, the Jardin des Sciences of the University of Strasbourg, the Cité des Sciences in Paris, and the International Space Station around the first mission of Thomas Pesquet. The conference gathered simultaneously 500 pupils in four cities for a video conference with Thomas Pesquet and four other French

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astronauts, in case contact with the space station was unavailable (which was, unfortunately, the case as Pesquet was called for an emergency spacewalk). In 2018, when Toulouse became the European City of Science, the event was even labeled by the EuroScience Open Forum (ESOF).

The main challenge of the event is the organization required to coordinate the various partners, namely a science museum, the institution in charge of primary education, and a university.

What to consider when reimplementing the described activity

As the national development of the event has shown, there is no doubt that this experiment could be extended to other cities and other partner countries. The potential challenge of the partnership convention lays in identifying partners involved in space research, or science in general, and ensuring that the terms of the Cité de l'Espace are scrupulously respected.

4.4.2 The Farm of the Stars

Short description of the activity

The Toulouse region has an abundant number of associations (the third sector of research) that facilitate the communication between scientists and citizens and provide very efficient channels for science communication. Three of them united under the name "La Ferme des Étoiles" (The Farm of the Stars) to organize several events in the field of sciences of the universe and the earth, sponsored by Hubert Reeves.

There are several events, locations, and activities all aiming to convey scientific space knowledge to a wide public. Among the highlights is the Festival d'Astronomie de Fleurance (Astronomy Festival of Fleurance), which was inaugurated in 1991 and has been operating ever since, though it was disrupted by the COVID-19 pandemic. Every year in August for an entire week, Fleurance, a little town in the Gers department, becomes the astronomy capital, with 40 scientists in residence for the duration of the festival. The festival has four main activities:

- The Science Marathon: a 12-hour session, from noon to midnight, during which 12 specialists (scientists, philosophers, writers, etc.) take turns analyzing a scientific topic from different perspectives.
- The Adult Festival: lectures, classes, workshops, exhibits, observation workshops, "Astro-cafés" for discussions with the guest speakers, etc.

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- The Village of Science: experimentation booths, scientific exhibitions, etc.
- The “Astro-Youth” Festival: animated by young researchers of the Institut de Recherche en Astrophysique et Planétologie (IRAP) of the Université Toulouse (campus Paul Sabatier) for children and teenagers aged 4 through 15. The 40 scientists in residence also participate in the youth festival.

Main objectives

The main objectives of La Ferme des Étoiles as stated on the website are:

- To help people, especially the younger generation, discover and enjoy science, and introduce them to or provide them with specialized training in astronomy, aeronautics, and astronautics.
- To explain the universe and humans’ place in it. To contribute to the raising awareness of the dangers threatening the earth and make people, especially the young, aware of the necessity to adopt new habits and develop a critical mind which, as the website indicates, is “at the basis of the scientific approach and the sine qua non condition of citizens’ freedom”.

Channels & tools

The activities take place at La Ferme des Étoiles, a farm in the department of Gers, Le Hameau des Étoiles (The Hamlet of the Stars), the only vacation camp in Europe entirely dedicated to astronomy, and the Pic du Midi (The Observatory of the University of Toulouse) located in the Central Pyrenees at an altitude of almost 3,000 meters. These three very different locations provide various audiences the opportunity to discover the sky, stars, planets, etc. in a perfect environment. The Ferme des Étoiles owns important scientific equipment such as flight simulators, telescopes, models, pedagogical equipment, etc., some transportable, some stationary. A detailed list is available on its website. It also allows access to specialized equipment of the University’s observatory. The association has numerous partners and an especially strong partnership with the University of Toulouse. The website is very well documented and contains articles, interviews, photos, and pedagogical material. It also provides the following resources: lectures and master classes offered during the festival, interviews, videos, podcasts, and the Rosetta Kit, a pedagogical kit that can be downloaded from the website.

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Target audience

The numerous scientific and cultural projects target various audiences. Some are precisely aimed at the younger generations (children from the age of 4), others at the general public. Some are initiation activities for people who want to discover science, others target hobbyists who already have some non-professional training in astronomy or astronautics. The Astronomy Festival is unique in organizing parallel activities for adults and children in a friendly family environment.

Output & impacts

The impacts of the project are many as it radiates throughout the region. It organizes complementary preparatory sessions in local schools, fosters debates, connects scientists and citizens, and gives a large number of people access to space science. The festival attracts large crowds, dynamizing the local economy of the region which otherwise attracts marginal tourism but offers excellent conditions to observe the sky.

Successes & challenges

The uninterrupted festival activities of the past 20 years give proof of their importance and popularity and are a good example of a successful partnership between science communication associations, hobbyists, and scholars.

What to consider when reimplementing the described activity

Beyond adapted locations and scientific equipment, a good synergy between the various actors (third sector associations, scientists, local infrastructures) is indispensable.

4.5 Université du Luxembourg/Luxembourg

4.5.1 Scienteens Lab

Short description of the activity

The Scienteens Lab (SL) is the University of Luxembourg's first research lab for high-school students in Luxembourg. It is an extracurricular learning center that offers workshops and activities designed to spark students' interest in science, show them the latest trends and

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technologies in research, support and encourage them to engage in higher education, and pursue a scientific career.

Logo of Scienteens Lab
© University of Luxembourg, Scienteens Lab

The Scienteens Lab was founded by the Luxembourg Centre for Systems Biomedicine (LCSB) in 2013 and is under the patronage of Her Royal Highness Crown Princess Stéphanie of Luxembourg. In 2016, the Faculty of Science, Technology and Medicine (FSTM) joined the initiative to offer additional scientific activities. The Scienteens Lab organizes hands-on experiments, supervised by experienced scientists and teachers from various disciplines, and provides the students an insight into scientific research and the day-to-day work in the lab. The workshops address relevant topics in biology, mathematics, physics, and computer science.

Main objectives

One of the main courses that SL offers is the Computer Science Program. The main objectives of the course are to make computer science accessible to all high school students, make them aware that computer programming can be applied to answer questions in all imaginable fields, allow them to learn some basic programming themselves, and thereby increase their programming literacy while at the same time taking away their fear to this subject. As with all the other topics taught at the SL, they also support students who develop a special interest in this subject, by helping them with additional internships at the University of Luxembourg and answering their questions related to job opportunities in this field.

Channels & tools

The main channels of the SL activities are in-person interactive workshops, classes, and scientific exhibitions. The interactive workshops allow students to apply their theoretical knowledge acquired from schoolbooks to real-life research activities. Aside from getting teenagers excited about applied research, the SL also wants to help students determine whether a career as a researcher would suit them. Since its founding in 2013, the SL has evolved from a tiny two-person initiative into a full-fledged extracurricular education center, teaching over one hundred workshops a year in biology, physics, mathematics, and most recently, also in computer science.

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Target audience

Though the main target audience for the Scienceteens Lab's activities are teenagers, and high-school students, it is currently also developing courses geared towards teachers as well as parents.

Output & impacts

Over the next 2 years, Scienceteens lab will develop 9 workshops for teenagers inspired by some of the most current and cutting-edge technology available in the field of computer science.

Successes & challenges

One of the main successes of the Scienceteens Lab is the summer Academy, where the Scienceteens Lab organizes one-week interdisciplinary workshops dedicated to high-school students aged 15 and over. These are unique opportunities to discover different scientific fields, perform lab experiments, work with other budding scientists and catch a glimpse of the life of a researcher. This year SL offers two different topics for the Scienteens Academies: a summer workshop on systems biology and sustainability, climate change, and renewable energies.

One of the challenges of the SL is that science, specifically computer science, is still very gender-biased. We, therefore, want to organize specific activities aimed at encouraging girls interested in this topic.

5 Best Practice Examples in the Field of Citizen Science

This chapter provides best practice examples in the field of citizen science. Best practices are cases that are especially innovative and have demonstrated success. Most of the examples are being or were implemented at UNIVERSEH's partner universities. Others were conducted in the universities' respective countries and chosen for their innovative character and/or focus on space-related topics. As the UNIVERSEH Alliance focuses on space education, the majority of the examples are in the domain of space science. Further citizen science activities in the field of space science can be found in Annex 2.

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This chapter aims to share experiences with scientists who are actively engaged in or planning to engage in citizen science activities with the public. It reflects a variety of citizen science activities and covers a wide range of objectives and participatory levels. The examples all follow the same structure and include a description of the activity, its objectives, channels, and tools used when implementing the project, target audience, outputs and impacts, successes and challenges, and recommendations for reimplementing the activity.

5.1 AGH University of Science and Technology/Poland

5.1.1 CREDO

Short description of the project

The Cosmic-Ray Extremely Distributed Observatory (CREDO) is an ongoing research project involving scientists and the public from around the world, dedicated to observing and studying cosmic rays and cosmic-ray ensembles [P. Homola, et al. (CREDO Collab.), Symmetry 2020, 12(11), 1835, 2020]. Thus far cosmic-ray research has focused on detecting single air showers while the search for ensembles of cosmic rays, which may overspread a significant fraction of the Earth, is an unexplored territory. As large-scale time correlations are the experimental goal of the project, the size of the CREDO network and the number of detecting stations is of critical importance. Hence, one of the key ideas of CREDO is to expand its network and involve non-scientists and their pocket devices in the experiment. Smartphones simultaneously help non-scientists to explore nature on a fundamental yet understandable level.

The concept of the Cosmic-Ray Extremely Distributed Observatory (CREDO): open on two ends (data upload and access), using both professional, dedicated cosmic-ray infrastructure and off-the-shelf detection solutions, including smartphones [P. Homola, et al. (CREDO Collab.), Symmetry 2020, 12(11), 1835, 2020. [arXiv:2010.08351, DOI:10.3390/sym12111835].
© AGH University of Science and Technology, CREDO

CREDO's strategy is based on the use of large-scale correlations of cosmic rays as a tool for a unique, bottom-up approach to scientific research. The project involves many citizen scientists who are not required to have any specialized knowledge or skills. It offers its project's participants the

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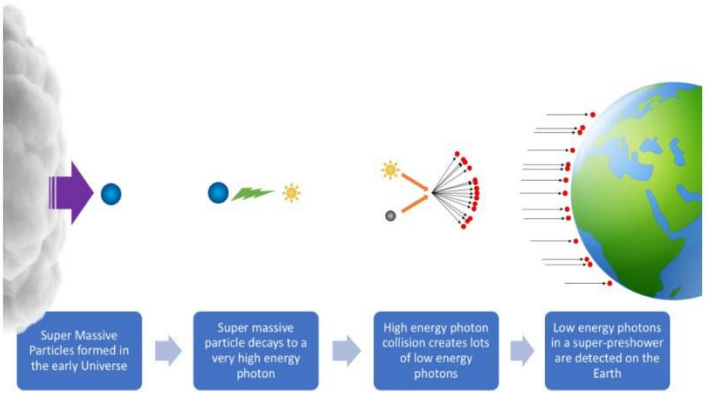
opportunity to experience science and become part of the scientific process, learn from professionals, and contribute to scientific research on cosmic ray ensembles (CRE). The CRE observations (or lack thereof) will provide a qualitatively new method of studying the Universe and a new information channel as part of a multi-band research strategy in the field of particle astrophysics.

The AGH contribution to this project is provided by the students taking part in the project.

Main objectives

The main goal of CREDO is to search for signatures of cosmic ray ensembles. These signatures should consist of numerous, at least two, spatially and temporally correlated large atmospheric bunches and/or individual particles of secondary cosmic rays reaching the Earth. Exploration of the possibilities of CRE as a signature of heavy dark matter or interactions of ultra-high energy cosmic rays (UHECRs) may allow us to find answers to one of the most intriguing puzzles in modern astrophysics: the origin of dark matter and of UHECRs, i.e. cosmic rays with energy above 10^20 eV.



The creation of particle cascades detectable on the Earth originating from massive particles in the early Universe
© AGH University of Science and Technology, CREDO

Existing observatories that are looking for particles from space are highly unlikely to recognize these super-preshower particles for what they are, as they cover only a tiny fraction of the Earth's surface. To identify these widely distributed showers a detector the size of the Earth would be needed, which is not possible. However, what is possible with public help, is to have lots and lots of little detectors spread out across the Earth's surface [ref: CREDO].

Tools & channels

- CREDO Detector Smartphone Application: The hardware needed for the application is a smartphone with a camera. By downloading the CREDO Detector App participants are able to detect the particles from space and become one of the worldwide CREDO detectors [link].

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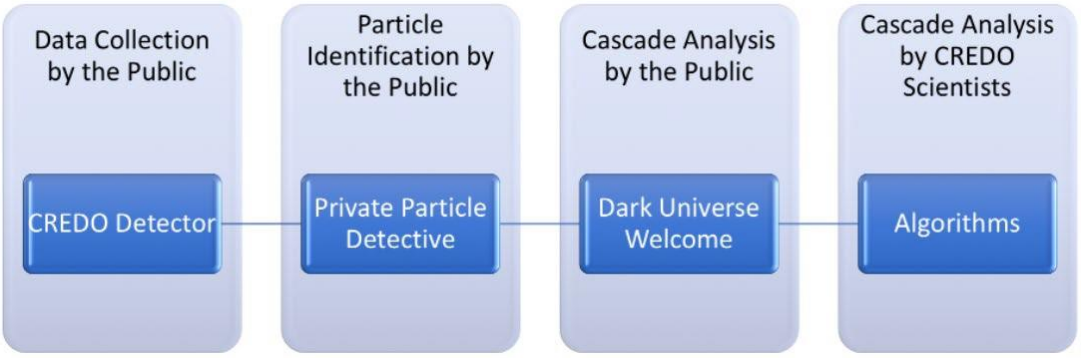
- Under development: Private Particle Detective allows you to follow particle detections through the analysis process.
- Dark Universe Welcome: This platform for data analysis takes confirmed and categorized detections from the Private Particle Detective and has CREDO supporters look for groups of detections in space and/or time. It is used to see all particle detections and thus the whole process of data analysis [link].

Here you can find a short tutorial on how to download and use the above tools.



The flow of particle detections through CREDO project and the role of the public and scientists in the project
© AGH University of Science and Technology, CREDO

Output & impact

The CREDO Detector Application enables mobile devices to detect particles of secondary cosmic radiation and local radioactivity. Indeed, the Cosmic-Ray Extremely Distributed Observatory enables everyone to take part in cutting-edge research, creating opportunities for enthusiasts to unlock answers, contribute to real discoveries and become a co-author of scientific publications. The "Particle Hunter", a team competition organized by CREDO, has aroused the interest of primary and secondary school pupils in cosmic rays. The competition has strengthened the young people's understanding of scientific work as well as their theoretical and methodological skills.

Successes & challenges

The success of the people-powered research project, for which CREDO stands, is the number of people involved in the project. And this is not only the main success of the project but also

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the main challenge for its researchers as it involves using social media, press, radio, and television, writing popular science articles, etc. The critical and creative thinking skills citizen scientists have gained in the process of doing their scientific work influenced other aspects of their daily life. CREDO's success in discovering new physical phenomena can be attributed to its observers who with their smartphones detect cosmic rays spread across the entire earth.

The CREDO project is supported by the VISEGRAD fund under grant number 21720040 and 21920298 and by the ASTERICS project [HORIZON 2020 Research and Innovation action under grant number 653477].

5.2 Heinrich Heine University Duesseldorf/Germany

5.2.1 Fridays for Future Meets Citizen Science

Short description of the project

Fridays for Future Meets Citizen Science was an innovative citizen science project that was initiated by Dr. Witold Mucha and Dr. Anna Soßdorf and involved not only researchers of the Institute of Social Sciences but also members of the global youth movement Fridays for Future. It was conducted from January 2020 to August 2021 and was funded by the Citizens' University of the Heinrich Heine University Duesseldorf. The research project differed from previous projects in its methodology. The activists were made part of the knowledge-producing process. In their role as co-researchers, they became equal partners and therefore had a say in all project matters such as determining the research question, the design of the study, the methodologies applied, etc. The project particularly focused on the decision-making process within the Fridays for Future movement, the question of how decisions are made, and which factors play a decisive role in the process. Collaboration between the researchers and the citizen scientists mainly took place in the workshops. Each workshop was dedicated to a specific step in the social science research process. Between the workshops, the research process continued using online tools. Having the activists on board allowed for a much more in-depth microanalysis of the Fridays for Future movement as the activists had an exclusive perspective of their movement and therefore offered comprehensive access to the field – a unique asset most studies do not hold.

Logo of the project
© Heinrich Heine University Duesseldorf, Fridays for Future Meets Citizen Science

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Main objectives

Although much has been written on Fridays for Future, only a little attention has been given to the decision-making processes of the movement in scientific discussion. This research project aimed at feeding into this research gap and contributing to the sparse empirical side of the debate. To gain an internal perspective of this youth phenomenon and generate inside knowledge to better understand the internal decision-making process, the project followed a participative approach. This approach aimed at integrating Fridays for Future activists from Duesseldorf as members of the organized civil society in the citizen science project. The methodological citizen science rationale is that the activists in their role as citizen scientists are better equipped to address the relevant questions and methods of their movement than traditional scholars as they are Friday for Future experts. Hence, the citizen science approach aimed at making the activists co-researchers and therewith co-producers of knowledge by including them in all phases of the research project and the decision-making process.

Tools & channels

As the project was conducted during the COVID-19 pandemic all meetings, events, and communication took place online. Therefore, workshops, as well as online events, were held via an online conference tool. Communication between project partners took place mainly via messenger and email. To make all relevant documents accessible to the team of researchers and co-researchers and facilitate the asynchronous joint work on these documents, multiple collaborative online tools were used. Public awareness of the project was raised mainly via the project website, its blog, and a citizen science platform. The project website provided information on the project's objectives as well as on how interested Fridays for Future activists could engage themselves in the project. The newest project developments, as well as reports on workshops and various other events conducted by citizen scientists and/or researchers, were published on the project blog. The project was introduced to the broader citizen science community within Germany via the prominent citizen science platform CitizensCreateKnowledge (Bürger schaffen Wissen).

Output & impact

This citizen science project not only strengthened the young activists' understanding of scientific work and their theoretical and methodological skills but simultaneously brought scientists closer to citizens. Unlocking the potential and expertise of citizens was an important factor for the success of this project and showed how citizens can play a key role in the production of scientific knowledge. The project not only contributed to closing a relevant

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research gap regarding the decision-making processes of the Fridays for Future movement but also respected the ideas and aims of the participating activists.

The research findings of a first survey on the effects of COVID-19 on the communication, organization, and mobilization of the Fridays for Future movement were published in an academic journal. The results of the decision-making process will be published forthcoming.

To make the findings easily accessible and understandable to the movement as well as to other interested activists a series of four videos were created. In these videos, the citizen scientists present and explain the research findings. Apart from contributing to the research of decision-making processes within the Fridays for Future movement, the project has contributed to the development of the citizen science approach, especially in the field of social sciences where it is not prevalent. The experiences gathered in the project were shared and discussed with the citizen science community in Germany as well as with other researchers at social science, science communication, and citizen science conferences. These experiences also fed into another publication on the role of competencies in citizen science.

Keyvisual of the project
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Successes & challenges

The citizen science approach proved valuable to the experienced scholars as the citizen scientists offered the project new perspectives. Through their input and expertise on the Fridays for Future movement, the citizen scientists shaped the direction of the research topic considerably. Additionally, the integration of Fridays for Future activists allowed for better access to the field. Regarding the activists' involvement in the project, their participation proved beneficial for them as well, as they acquired theoretical and methodological skills in the field of social sciences and gained deeper insight into their movement.

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Discussion of the key results of the project
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At the same time, researchers were faced with challenges during the co-creation process. Bureaucratic requirements such as data protection obstacles had to be overcome, which slowed down the process of online co-creation at the project's start. Keeping the citizen scientists motivated and committed to the project and the dropout rate low proved to be a further hurdle. This required maintaining a constant flow of communication between researchers and citizen scientists, which in turn involved a great deal of human resources. To enable all project partners to conduct research on equal terms a common language needed to be found. This included breaking down complex scientific theories and discussions into a generally intelligible language. Closely linked to the project's aspiration of involving citizen scientists on equal terms, was the fear that researchers may experience some loss of control over the scientific process, as they were no longer solely making decisions regarding the project. The citizen scientists were challenged with understanding the concept of citizen science and finding their role within the project, especially at the beginning of their involvement. Some needed time to develop the courage to engage themselves in the project and voice their ideas and opinions. As the citizen scientists were co-researchers on the one hand and activists of the movement investigated on the other, some of them experienced loyalty conflicts. A further challenge caused by the COVID-19 pandemic was the exclusive virtual exchange for the entire duration of the citizen science project. Although it made participation in the workshops easier, as no travel was involved, becoming closer acquainted was difficult.

<u>What to consider when reimplementing the described activity</u>

Citizen scientists are new to the field of research and need time to adjust to the situation and their new role as scientists. When working with citizen scientists an atmosphere of trust is essential and can be created by establishing and cultivating a culture of open communication and overcoming hierarchy. This involves acknowledging citizen scientists' perspectives, asking for their input, and recognizing the value of their knowledge and expertise to the project and research progress. They need to be encouraged to speak their views and express their expectations, to be informed on the progress of the project regularly, and to be appreciated for

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their work. For the Fridays for Future Meets Citizen Science project, it proved helpful to ask the participating citizen scientists for feedback and to incorporate their thoughts into the project's further work. As communication is a key factor for the success of a citizen science project, researchers need to calculate sufficient human resources for communication purposes. Of equal importance is that researchers reflect upon the citizen science approach and the factors involved in implementing a citizen science project as well as one's role in the project.

5.2.2 Cosmological Jellyfish

Short description of the project

Cosmological Jellyfish was a citizen science project of the Scientific Department of Galaxies and Cosmology at the Max Planck Institute for Astronomy in Heidelberg. The project was initiated and conducted by a group of researchers under the leadership of Annalisa Pillepich from June to November 2021. The project aimed to identify galaxies that look like jellyfish. Jellyfish galaxies are galaxies that trail the remnants of their gas behind them and therefore visually resemble jellyfish trailing their tentacles. Citizen scientists supported the researchers by viewing thousands of galaxy images extracted from so-called cosmological simulations in search of jellyfish galaxies. Every galaxy in the simulation was classified by at least twenty individuals. This procedure allowed the researchers to take the average consensus in their analysis and not have to depend on a single classification. By taking the consensus between the citizen scientists into account, the researchers also learned which galaxies were difficult to classify and that in itself was valuable information.

Main objectives

The Cosmological Jellyfish project aimed to identify galaxies that look like jellyfish to understand how these galaxies are formed, how they interact with their environment, and what impact these interactions have on them. Volunteers, that is citizen scientists, were therefore essential for the success of the project. Using images from cosmological simulations, they helped researchers by distinguishing between galaxies that appeared normal and those that looked like jellyfish.

Channels & tools

As the formation of a cosmic jellyfish galaxy is a process that occurs over hundreds of millions of years, it is impossible to observe the formation in real-time. The project, therefore, used

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cosmological simulations to create a model of the universe that follows the same laws of physics as our cosmos. In this virtual universe stars and galaxies resemble those in the cosmos. Cosmological Jellyfish used data from the IllustrisTNG numerical simulations to classify the galaxies. Citizen scientists looked at the galaxy images and classified them as jellyfish galaxies or normal galaxies. As several tens of thousands of satellite galaxies needed to be classified, the help of citizen scientists was crucial. To recruit sufficient volunteers to classify the galaxies, the project members created a project page for Cosmological Jellyfish on Zooniverse, a global citizen science platform where citizens can find people-powered research projects and contribute to scientific research. Information concerning the Cosmological Jellyfish project and how to become involved could be found on the project page. The project team also designed a step-by-step tutorial to guide participants through the process of classifying galaxies and provided examples to illustrate the differences between galaxies and jellyfish galaxies.

Output & input

The project attracted the support of approximately 4,500 participants between June and November 2021. Within this timespan the citizen scientists inspected more than 80,000 images, each image being classified by at least 20 individuals. This allowed the researchers to proceed with their quantitative analysis of the simulated galaxies. A first scientific publication based on the visual classifications of the citizen scientists is currently being prepared.

Successes & challenges

The project Cosmological Jellyfish was very successful in arousing interest in their project and recruiting citizen scientists. During the first phase of the project in June 2021, approximately 38,000 images were inspected by a few thousand volunteers in less than two weeks, every image being inspected by at least 20 individuals. By November 2021, two data sets were completed.

The project's team encountered very few practical and organizational challenges, which they attributed to the use of the online platform Zooniverse. They were, therefore, able to focus on the substantial aspects of the project such as making sure the questions for the citizen scientists were well formulated, easy to understand and act upon as well as useful for the researchers' scientific projects. The team provided citizen scientists with additional information on galaxies which was not necessarily needed to complete their task of classifying but nonetheless of interest. Whether this motivated citizen scientists and/or was useful for them is hard to determine.

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What to consider when reimplementing the described activity

When planning a citizen science project, the Cosmological Jellyfish team finds it very important to keep the task that is to be completed by the citizen scientists simple. In the case of Cosmological Jellyfish, the task was very simple. The volunteers were asked to inspect an image, reply to a yes/no question, and then continue to the next image. The project's team also recommends using already existing platforms such as the citizen science platform Zooinverse. Many of the available platforms are well designed and very functional while developing a new infrastructure for a project most often involves a great deal of time and can be costly.

5.3 Luleå University of Technology/Sweden

5.3.1 Botnia Living Lab

Short description of the activity

Botnia Living Lab is not an activity but a concept and method on how to use citizens in research and innovation processes. Botnia Living Lab has been used for numerous research projects during the last decade. It is an environment for citizen science, user-centric research, development, and innovation. The lab is a user-panel and consisting of thousands of people from all over Sweden. Since its beginning, it has been an important booster in the creation of novel and valuable IT services and products as well as for research. The volunteers contribute to research in a non-controlled environment under real-life conditions. Usually, their input is given already at a conceptual and immature level of the research.

The panel of citizen volunteers has been involved in a significant number of research and innovation activities, with researchers and companies from Sweden and abroad and in several different application areas related to for example Smart Cities.

To support the process, researchers have developed a Living Lab methodology named FormIT, adopted by many Living Labs around Europe and exploited by industry. This methodology supports user involvement when developing digital innovations. It´s also a methodology for user empowerment, to capitalize on the strength of the crowd. This is an iterative and interactive innovation-process methodology with user engagement in all phases of the innovation process.

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Main objectives

The main objective of Botnia Living Lab is to engage citizens in various ways in the total research and innovation process, from need-finding and idea-generation, through concept-development and prototype and usability testing to service piloting.

Channels & tools

We reach out to and communicate with the volunteers through e-mails, social media, physical meetings, and workshops. When we collect data and input from them, the channels are quite overlapping: surveys, e-mails, physical meetings, and workshops.

Output & impacts

When engaging citizens in a Botnia Living Lab, the goal is always to achieve social inclusion, equity, and democracy. Anyone who wants to contribute should be able to do so. Citizens, “ordinary people”, become decision-makers and have for example a real impact on the output of a research result or an innovation. When citizen engagement is carried out democratically and inclusively way, the result will be more easily adopted by future users.

Successes & challenges

In Botnia Living Lab, we have learned that there are two main challenges when using citizen science. First, recruiting and attracting people to get involved in the projects. Secondly, keeping the people engaged throughout the entire process. We can’t force volunteers to stay with us for the whole journey of a project. Some of them always drop out.

A successful aspect of Botnia Living Lab is that whatever is developed together with citizens, will always be adopted easier and receive higher acceptance by the end-users. This co-creation enables researchers to create value both for research and people.

What to consider when reimplementing the described activity

When it comes to citizen science, we have learned that it is important to engage the citizens early! From our experience, one key to success is maturity and early engagement. Another key is to always be inclusive, aim at creating a democratic setting, have a distinct research purpose, and know why citizen engagement is important.

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Citizen science can create amazing and unexpected synergies and it is a good idea to keep an open and generous mind. When engaging citizens, allow the main core of the research to be citizen science and support it with expertise (researchers), not the other way around.

5.3.2 Skinnkollen (The Food Waste Experiment)

Short description of the activity

The Food Waste Experiment was carried out for three weeks in November 2020. It was a collaboration between the company Consupedia, Dalarna University, and the KTH Royal Institute of Technology. In the Food Waste Experiment, researchers developed and tested a new way to reduce food waste in Swedish schools that serve free lunches to their pupils, by providing more information and individual feedback. During the Food Waste Experiment, teachers and pupils helped develop an app to find out how much food they threw away. In the first week, teachers and pupils used the app to train the AI to identify different kinds of food. In the two following weeks, they used the app to photograph their plates before and after eating, allowing the app to calculate how much food was wasted. Before lunch, they received information about what was being served that day, the nutritional content of the dish, and its climate footprint.

The researchers wanted to find out if it is possible to create virtuous food cycles illustrating how food is dealt with, all the way from the wholesalers to the pupils. If pupils were more aware of how their food is affecting the climate, their health, and the environment, it may lead to more conscious choices in the canteen. Also, if school kitchens have better information about what foods the children like and dislike, menus can be adapted to better suit the pupils' needs and likes, kitchens can make more tailored orders from the wholesalers and further reduce the amount of waste.

Main objectives

The main objective of the experiment was to investigate if it is possible to calculate food waste and its climate impact with AI in a smartphone app and to explore whether more and better individual information and feedback could result in more climate-friendly food choices and less food waste. The app used in the project had two purposes: to inform the pupils about the school menu and how the production of that food affected the climate and to calculate the waste's environmental impact.

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Channels & tools

The children used an app to contribute to the investigation. Before eating, the app identified the dishes, when finished eating, the app measured the waste left on the plate.

Output & impacts

About 700 pupils from 27 Swedish schools were engaged in the project. The app, the AI of the application, learned to identify a lot of different dishes thanks to the children. One of the questions investigated in the project was if it is possible to measure food waste with AI. The answer was yes! The AI learned a lot during the experiment and identified 70 % of the food pictures correctly. The other question could also be answered with yes: it is possible to reduce food waste by informing the pupils and giving them feedback. When comparing the food waste of the first three days of the experiment with the last three days, the waste decreased by 16 %.

Successes & challenges

One challenge of the experiment was the uncertainty of the AI application performance. But after just one week of training, the app did a great job recognizing different dishes and measuring the amount of waste left on the plates.

The pupils learned a lot during the experiment as well, since the amount of waste decreased. The researchers also noticed another interesting aspect: there is a correlation between how full the pupils are, how much time they spend eating (the average eating time was 10 minutes and 24 seconds), and how much they throw away. Pupils who are full and sit at the table for quite a long time, generate less waste. Beyond that – if they like the food – the waste decreases even more.

What to consider when reimplementing the described activity

In their project report, the researchers state that the project has great potential for continuous development. They point out further areas of investigation, for example, the impact noise has on waste, does a noisy environment contribute to less quality eating time and hence to more waste? Another possibility would be to use the app to determine how much food pupils eat and if they get enough nutrition in school.

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hhu Heinrich Heine Universität Düsseldorf

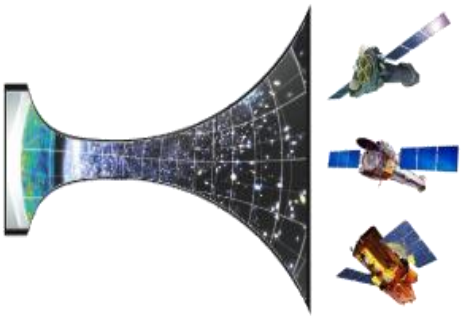
Another thought is how difficult it is to break habits, as it requires repetition and continuous reminders. Therefore, it would be a great idea to repeat the Food Waste Experiment every semester, slowly teaching the pupils to change their behavior and contribute to less waste and in the end, a smaller climate footprint.

5.4 Université Fédérale Toulouse Midi-Pyrénées/France

5.4.1 CLAXSON

Short description of the activity

The Institute of Research in Astrophysics and Planetology (Institut de Recherche en Astrophysique et Planétologie, IRAP) of the Université de Toulouse (Campus Paul Sabatier) has launched a new citizen science project: CLAXSON (Classification of X-ray Sources for Novices). On the 21st anniversary of the launching of the XXM-Newton in 2019, the X-ray Observatory of the European Space Agency and the XMM-Newton Survey Science Center (XMM-SCC), which is a consortium of three French, two German, two British, and one Spanish institution, published a new catalog (4XMM-DR10) containing 849,991 X-ray detections extracted from 11,647 observations made by the satellite.



Logo of CLAXSON
© University of Toulouse, Nathalie Dessens

To help identify these sources, notably consisting of supermassive black holes (Active Galactic Nuclei) and rarer objects such as X-ray binaries, IRAP has conceived the CLAXSON website which enables citizens to help astronomers. It trains people to identify the objects contained in the 4XMM-DR10 catalog. Once they have learned this process, they can look for black holes on their own.

Main objectives

The main objective is to build a sufficiently large reference sample to enable a computer to identify the objects detected. Over half a million objects have been found by XMM-Newton and individual identification of these objects is a very long process. As the website indicates, CLAXSON will enable citizens to "classify X-ray celestial sources […] and help shed light on the high-energy Universe by making new astrophysical discoveries". Thanks to the help of

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CLAXSON users, it will be possible to gather larger samples of known sources, so that machine learning experiments can identify the remaining sources more reliably. A secondary aim of the website is the identification of some outliers, not belonging to the usual X-ray source types, which often carry great scientific value. These achievements can potentially be of great help to scientists and the general public to better understand black hole populations.

Channels & tools

The tools used in this activity are the 4XMM-DR10 catalog and the CLAXSON website. The website provides training that enables citizens to explore space and discover still unidentified supermassive black holes, stars, and other objects. The tutorial is informative and entertaining.

Target audience

Although the website has a space reserved for astronomers, the target audience is the general public who, after self-training on the website, will be able to participate in the detection process to help build the large sample required by IA. The project is accessible in French, English, Greek, Spanish, and Italian.

Output & impacts

Since the project is just emerging, participants are currently students, researchers, and people interested in science who have been informed about the project through lectures or the newsletter connected to the activity of a telescope. One year after the first release of the CLAXSON website, about 150 users had provided more than 75 000 classifications. The translation of the website into four foreign languages made it easy to extend the experiment to the European public. In 2022, CLAXSON was used in several classes in Spain and France to introduce college students to X-ray astronomy. This activity was very well received by the students and teachers found it a good pedagogical resource. Some students continued taking part in the experiment in their free time. A survey sent to the first users in early May confirmed this excellent feedback. Half of the ten respondents, including 60% French speakers and a wide diversity of profiles, found that using CLAXSON was “a lot of fun”, more than half felt they were “contributing to science”, and one-third became interested in X-ray astronomy thanks to the experiment.

It is too early to properly assess the scientific impact of the experiment because only 115 objects have been classified by more than 20 users and are thus considered robustly classified by citizen science. However, a preliminary analysis of these 115 sources showed excellent

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reliability of their classifications, even better than that achieved by a state-of-the-art machine learning approach.

Successes & challenges

The development process of CLAXSON started in early 2020 with the twofold goal of increasing the samples of identified X-ray sources and making serendipitous discoveries that are commonplace in X-ray astronomy. The dataset shown to users and the classes they are asked to recognize were carefully chosen, to keep the exercise easy enough while ensuring a good scientific return. The choice of two user levels and a ranking was motivated by the desire to provide a playful platform to users and increase the quality and quantity of their classifications.

The first challenge was the development of a new website from scratch. A lot of citizen science experiments use the Zooniverse platform, dedicated to citizen science, as support. It comes with a large pool of initial users and makes the launch of an experiment fast and easy. However, it includes a limited number of features, and the integration of external web applications is not yet possible. The online virtual observatory tool Aladin Lite was required in this specific experiment, making it easy to visualize several images at one time and making them easily zoomable without requiring any large data upload, motivating the launch of a new website.

In late 2020, the website could finally be launched in its preliminary version, requiring the contribution of beta-testers to ensure its functionality. First feedback led to the conclusion that the experiment was very promising, provided that a class was removed. This proved that a complex task such as the classification of an X-ray source, involving the inspection of several images and figures, is still doable in a citizen science experiment thanks to an appropriate training phase.

A big surprise was the involvement in the experiment, of some users who performed dozens of classifications daily for several months (three users have made half of all the classifications collected so far). Their impressive performance makes the experiment very promising for the next few months.

However, keeping most users engaged in the long term has been challenging until recently. Feedback obtained from the user survey reveals that this is due to the absence of notifications sent to users, who end up forgetting to use CLAXSON. The recent implementation of user-adjustable notification emails and a weekly ranking is a way to address this issue.

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What to consider when reimplementing the described activity

Ensuring the scientific outcome

The first thing to have in mind is probably the output one wants to collect from users. If it requires a certain amount of knowledge to be completed, such as a familiarity with different object classes and what they look like, the implementation of a training phase on known objects can be very useful – although this phase has to be short enough not to discourage users. The possibility for volunteers to comment on an individual object is a simple way to allow them to contribute more if they want, and the analysis of their comments, though time-consuming, makes room for more serendipitous discoveries.

Using the proper platform

If the features available on specialized platforms such as Zooniverse are sufficient to develop the experiment, developers should consider using them: they provide sensible advice, a user-friendly interface for both developers and users, and are already well-known and trustworthy to the general public. If some features specific to the experiment are needed, however, the launch of a new website is also an option.

The right dose of gamification

When a volunteer starts taking part in the experiment, it is often due to either a curiosity about the scientific topic or the desire to contribute to science. However, to make them stay in the longer term, it is important to gamify the process for example by adding a ranking of achievements. However, caution is necessary not to affect the scientific return of the experiment, which could be the case, for example, if users were encouraged to make their classifications as fast as possible.

Beta-testing and feedback

When the experiment is first launched, a beta-testing phase often proves valuable to make the necessary adjustments, render it more user-friendly, and boost its scientific potential. This is particularly the case if the protocol was conceived by experts in the topic. Even in that case, it is still possible to define the next steps of the experiments together with a panel of volunteers, for example by asking for their feedback (with open and closed questions) in a user survey.

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Regardless of these considerations, a regular follow-up of the experiment by a scientist is always preferable.

5.4.2 Guardian of the Stars

Short description of the activity

The citizen science project described below is part of the larger project of the Réserve Internationale de Ciel Étoilé du Pic du Midi (RICE), dedicated to the protection and preservation of the quality of the night in the fight against light pollution. In 2013 it was designated a European Sky Reserve by the International Dark-Sky Association, the first and only one in France to this day. The RICE includes 247 municipalities and covers 3,300 km^2 (see map). The aim of the RICE is multifold: educating the public and influencing local authorities to replace the traditional lighting devices with eco-friendly ones. The project organizes many activities such as night hikes, astronomical observations, exhibitions, workshops, lectures, debates, etc.

The project also initiated a program dedicated to children called “Les petits citoyens de la nuit”, as local authorities recognized the importance of raising awareness among the area’s population, especially children, of environmental issues. As renewable energy is part of the seventh-grade curriculum, a pedagogical kit (slideshow, pedagogical guide, poster, magnets, narrated story, drawing activities, etc.) was developed and tested in four seventh-grade classes in workshops devised to assess the impact of the kit on the children. The aim of the project was not only to make children and their parents aware of the negative effects light has on biodiversity and health and of the necessity to reduce light pollution but also, through sensitive and poetic experiments, to make them like the night. The children’s drawings were exhibited at the end of the program.

Finally, RICE also initiated a citizen science project called Gardien des étoiles (Guardian of the Stars), a network of volunteers, which is described below.

Main objectives

The main objective of the Gardien des Étoiles is to assess the quality of the sky using citizens’ observations.

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Channels & tools

As indicated on the website, the tools used in this citizen science project are the human eye and cell phones. Participants download the mobile application “Ciel en peril” (Endangered Sky) and use it to observe the progression of light pollution in the RICE area, but also more widely in the Pyrenees as well as worldwide, and feed these observations into an international database used by many scientific projects.

Target audience

The target audience is the general public.

Output & impacts

Preserving the night is no longer just an astronomers’ problem but has now become a cultural, environmental, and ecological stake. Involving the public, children included, raises awareness of the problem, and enables more efficient leverage on local authorities.

Successes & challenges

The project has proved efficient as a large portion of the population participates as volunteers in the project, thus ensuring the support of local authorities. It is important to accompany the project itself by raising awareness of multiple segments of the population.

What to consider when reimplementing the described activity

The success of the project can be attributed to the many awareness-raising experiments (in this case the various activities organized for the public, workshops for children, teachers’ involvement, etc.) and the strong support of the local authorities. Yet indispensable for the success of such a project is not only a strong commitment from the participating scientists, schools, associations, and local authorities but also a good organizational team to coordinate the various actors and activities.

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5.5 Université du Luxembourg/Luxembourg

5.5.1 Public History as the New Citizen Science of the Past (PHACS)

Short description of the activity

Public History as the New Citizen Science of the Past (PHACS) develops public history and participatory models for interpreting the past. PHACS is hosted at C²DH, the Luxembourg Centre for Contemporary and Digital History, and is the University of Luxembourg's third interdisciplinary research center, focusing on high-quality research, analysis, and public dissemination in the field of contemporary Luxembourgish and European history. It promotes an interdisciplinary approach with a particular focus on new digital methods and tools for historical research and teaching. PHACS is inspired by the evolution of digital participatory sciences; PHACS facilitates interactions between academics, cultural institutions, groups, associations, and the general public to contribute to democratization not only of access but also of the production of history. Led by Prof. Thomas Cauvin, the team proposes, develops, constructs, and evaluates innovative participatory frameworks to engage and empower groups, associations, and users in critical debates on the contemporary history of Luxembourg and Europe. To make public history the new citizen science of the past, PHACS is working on five main areas with multiple partners in Europe:

- Public History and Participation in Museums
- Participatory Urban Projects: Public History in Esch-sur-Alzette
- Rethinking Shared Authority and Coproduction in Public History
- A History of Public Historical Practices in Europe
- Developing European Networks of Public History Courses, Programmes, and Training

The project is Funded by a 5-year ATTRACT research grant (2020-2025) from the FNR.

Main objectives

Public History as the New Citizen Science of the Past (PHACS) main aim focuses on the production of history with a public perspective. Public history has developed as one of the most dynamic international fields of the historical discipline. PHACS's objective is to contribute to reshaping public history methodology. Ph.D. research and projects may for instance focus on (but are not limited to) participatory exhibitions in museums, crowdsourcing cultural heritage, digital public history collections, community-based activities, or historical performances.

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Research and projects can be done in partnership with local or national partnering cultural institutions.

Channels & tools

Participatory exhibitions in museums, crowdsourcing cultural heritage, digital public history collections, community-based activities, or historical performances.

Target audience

Ph.D. researchers, local or national partnering cultural institutions, and public audience.

Output & impacts

- Research on a history thesis in the domain of contemporary history
- Development and evaluation of participatory practices in public history
- Contribution to the development of public history training in Europe

5.5.2 Eisegaart

Short description of the activity

The collaborative citizen research project 'Eisegaart' involves community gardeners, allotment holders, and natural and social scientists from the Natural History Museum and CELL, the Centre for Ecological Learning Luxembourg. The project aims to produce knowledge that is of interest to both gardeners and scientists. To ensure that the results of the research are statistically representative, 30 gardens have been included in the project. The garden types that qualify for the project are those that are entirely managed by the commune, those that have a mixture of individual and communal plots, and communal plots of city gardens situated on the same site. The exact research questions are still being determined by the project's gardeners and experts.

Main objectives

The project aims to train community garden facilitators and develop a website that enables citizens to find a community garden. The idea is to create a seed production with the help of

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artisanal seed producers, who are at present very active due to the hiegh demand for seed. Its objective is to determine how to engage citizens in participatory research, and how to involve them in all stages of the research process from defining the research question, creating interdisciplinary teams to tackle the research questions as well as to identifying reasons for the success of the project. The project is to combine research and permaculture. The Ministry of the Environment and the National Research Foundation have funded the project with €40,000.

Logo of Eisegaart
© University of Luxembourg, CELL

Channels & tools

The project's main channel is its participative website, everyone can contribute to the site by sending useful information. The 'seed network' organizes the 'Eisegaart' projects' yearly activities, such as garden forums, plant exchanges, and various training and workshops. The courses are open to the public and usually take place outdoors and/or online allowing participants to learn, for example, how to make a cultivation plan, how to include wild vegetables in their garden, or how to create vermicompost.

Target audience

The main target audience of the 'Eisegaart' project are gardeners, people who are interested in gardening, and scientists. The project created a so-called "seed network" which includes communal and private gardeners who came together to develop a Luxembourgish citizen seed network.

Output & impacts

Thus far, three participative citizen research projects have been conducted. One of the projects in 2021 was developed entirely by gardeners with the support of two scientists. Their interest in diversified cultures was fuelled by the fact that common gardens are often small and urban spaces. The research question underlying the project was if vegetable production changes in two mixed cultures of varying densities. The outcome of the project can be read here.

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6 Conclusion

The purpose of this best practice report was to identify already existing structures and experiences in the field of science communication and citizen science and to collect best practice examples. The best practice examples presented in the report show a wide variety of activities and projects as well as tools and channels implemented in science communication and citizen science activities amongst the alliance members.

It becomes apparent, that in general, the alliance partners share a similar understanding of science communication and citizen science. Both terms however are not always clearly defined. This is reflected in institutional structures and funding opportunities that vary considerably amongst the alliance partners. These structures seem to have an impact on the degree to which science communication and citizen science are incorporated and implemented at the respective universities. In contrast to citizen science, science communication is generally more established and recognized as the university's third mission and as such included in the university's dissemination and public engagement/outreach strategies. Citizen science on the other hand has not yet reached the same level of institutional commitment and recognition amongst/by all the alliance partners. This becomes apparent in fewer funding options and infrastructure to support scientists' engagement in citizen science leading to an overall smaller number of activities in this field. Another influencing factor leading to this outcome is that the concept of citizen science is not equally known in all alliance member countries. While in France and Germany a concrete understanding has been developed, in other countries such as Luxembourg, Poland, and Sweeden the concept is just being explored and communities are starting to build. According to Haklay et al. 2021, these differences originate in cultural differences and different historical trajectories. The authors of this report, therefore, see great potential to advance citizen science amongst the alliance partners and to bring forth innovative projects in a variety of disciplines.

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Annex 1 – Further Science Communication Examples in the Field of Space Science

Format	Activity	Country
Blog	ESA blogs	Europe
	Horizon.actu	France
	Rêve d'espace	France
	Phil Plait's Bad Astronomy,	USA
	Planetary Society Blog	USA
Digital Media	ESA Web TV	Europe
	Raumzeit	Germany
	CNES Website	France
	Echoscience Occitanie: e.g. https://www.echosciences-sud.fr/articles/vulgariser-l-espace-l-odyssee-de-thomas-charpenet	France
	Société astronomique de France	France
	NASA Television	USA
Discussion	Café und Kosmos	Germany
	Changing Skies	Germany
Event	Astronomy On Tap – Drink in the Universe!	USA/Global
	Guerilla Astronomy	USA
	Various events at the Cité de l'Espace	France
	Launching of the Webb	France
Exhibition	Astronomy To Go	Austria
	Up to Space	Germany
	Observatoire Midi-Pyrénées (OMP)	France
Lab	DLR_School_Lab	Germany
Lectures	Pourquoi continuer à aller dans l'espace?	France
Podcast	Podcastscience.fm	France
	Odyssée	France
	Day to Day	Germany/Europe
	Space Junk Podcast by Annie Handmer	Australia
Social Media	Erin Winick on TikTok and Instagram	USA
Support for teachers	Observatoire Midi-Pyrénées (OMP)	France
	L'Espace éducation	France
	CNES Toulouse	France
Videos	AFA (Association Française d'Astronomie) You Tube Channel	France
	Cafés Alpha	France

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Visualization	OpenSpace	USA/Global

Annex 2 – Further Examples of Popular Citizen Science Projects in the Field of Space Science

Project	Country/Region
Observatoire Participatif des Espèces de la Nature (OPEN)	France
Active Asteroids	USA
AI4Mars	USA
Astronomy Rewind	USA
Aurora Zoo	UK
Backyard Worlds: Planet 9	USA
Bursts from Space	Canada
Citizen ASAS-SN	USA
Dark Energy Explorers	USA
Disk Detective	USA
Einstein@Home	Germany/USA/Global
Galaxy Zoo	Global
Galaxy Zoo Mobile	Global
Gravity Spy	USA, Global
GWitchHunters	Italy, Global
Planet Four	USA, Global
Planet Hunters NGTS	Global
Planet Hunters TESS	USA, Global
Radio Galaxy Zoo: LOFAR	Netherlands, Global
Radio Meteor Zoo	Belgium
Seti@home	USA, Global
Solar Stormwatch II	UK, Global
Stardust@home	USA, Global
Star Notes	USA
SuperWASP: Black Hole Hunters	UK
SuperWASP Variable Stars	UK
Zwicky's Quirky Transients	Global

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