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## **Co-creation Processes Contributing to the Societal Impact of Science: Contributions from the Net4Impact Network**

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# **Co-creation Processes Contributing to the Societal Impact of Science: Contributions from the Net4Impact Network**

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## **Abstract**

Meaningful citizen participation throughout the development of research projects has increased the societal impact of science. Co-creation processes promote a more significant societal impact by aligning research with societal needs. In recent years, essential advances in citizen participation in science have been identified. However, there are still critical challenges that limit citizen interaction with scientific creations. This article provides some of the contributions made by the Net4Impact network in the face of these challenges. Specifically, we analyse co-creation processes developed by those projects that have demonstrated societal impact. This qualitative study is based on the analysis of Webinars, meetings with researchers from different scientific areas and Communicative Content Analysis. As a result, this work provides six examples of societal impact in three scientific areas: social sciences, humanities, and engineering. In addition, we analyse the characteristics and implications of the different co-creation processes developed by these successful projects.

**Keywords:** co-creation, societal impact, science, citizenship, involvement

# **Procesos de Cocreación que Contribuyen al Impacto Social de la Ciencia: Aportaciones de la Red Net4Impact**

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## **Resumen**

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La participación ciudadana a lo largo del desarrollo de los proyectos de investigación ha demostrado aumentar el impacto social de la ciencia. Los procesos de cocreación promueven un impacto social más significativo al alinear la investigación con las necesidades sociales. En los últimos años se han identificado importantes avances en materia de participación ciudadana en la ciencia. Sin embargo, todavía existen importantes retos que limitan la interacción de la ciudadanía con las creaciones científicas. Este artículo recoge algunas de las aportaciones de la red Net4Impact frente a estos retos. Concretamente, analizamos los procesos de cocreación desarrollados por proyectos que han demostrado impacto social. Este estudio cualitativo se basa en el análisis de *Webinars*, reuniones con investigadores de diferentes áreas científicas y en el Análisis de Contenido Comunicativo. Como resultado, este trabajo ofrece seis ejemplos de impacto social en tres áreas científicas: ciencias sociales, humanidades e ingeniería. Además, se analizan las características e implicaciones de los distintos procesos de cocreación desarrollados por estos proyectos exitosos.

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**Palabras clave:** cocreación, impacto social, ciencia, ciudadanía, participación

Meaningful citizen engagement throughout the development of research projects has generated a wide range of benefits for both science and citizens (Evans et al., 2005; Freitag & Pfeffer, 2013). From the citizen perspective, benefits identified include educating the public in science and scientific thinking or a greater appreciation of their community's natural or cultural heritage (Cohn, 2008). Furthermore, incorporating diverse perspectives into analysing an issue increases its understanding and offers better solutions to social challenges (Freitag & Pfeffer, 2013). Thus, co-creation processes promote science's more significant societal impact by aligning research needs with societal needs (Van den Besselaar et al., 2018).

In recent years, fundamental advances in citizen engagement in science have been identified. However, there are still significant challenges in both the interaction of citizens with scientific developments and their motivation to participate in scientific activities (Heinisch, 2021). In addition, more knowledge is needed on research methodologies that have established a significant engagement with non-scientist citizens (Druschke & Seltzer, 2012; Rock et al., 2018).

This article arises from the contribution provided by the Net4Impact<sup>1</sup> research network. Net4Impact has set itself the need to overcome challenges outlined above. The network aims to make visible and reinforce the societal impact of Spanish research. To this end, it has promoted the joint work of researchers with outstanding careers in societal impact in five areas of knowledge: social sciences, humanities, engineering, mathematics, and environmental sciences. Specifically, this article reports examples of societal impact identified by the network in which co-creation processes have played an essential role.

We present state of art on science's societal impact and co-creation processes in the following. Secondly, we provide the methodology used in the research, which is based on a qualitative study on the analysis of multidisciplinary Webinars and meetings, and the Communicative Content Analysis on projects that have demonstrated societal impacts (Pulido et al., 2020). Thirdly, the results are provided. These focus on the analysis of co-creation processes that have contributed to the societal impact of research in three areas of knowledge: social sciences, humanities, and engineering. Finally, the main contributions and conclusions of the research are presented.

## **The Societal Impact of Science**

In December 2019, the first cases of SARS-CoV-2.7 disease were identified. Three months later, the World Health Organization decreed that it was a global pandemic (WHO, 2020). In January 2022, there have been about 300 million confirmed cases of COVID-19, including about 5.5 million deaths reported (WHO, 2022). The COVID-19 pandemic has led governments and citizens to see science as one of the main ways out of this health emergency (Pulido Rodríguez et al., 2020). Furthermore, researchers from different areas of knowledge have joined forces to generate interdisciplinary solutions to the significant challenges posed by the pandemic (European Union, 2020). This scenario has highlighted the need to focus scientific research on solving the main social problems and, therefore, on generating societal impact.

The societal impact of research occurs when the published and disseminated research results, which have been transferred, improve the objectives agreed and prioritised in our societies (Aiello et al., 2021). In the case of European research, this would imply considering common societal goals or objectives set, for example, from the European Council's Strategic Agenda for 2019-2024 (European Council, 2019). At the international level, it would be related to the contribution from the various scientific areas to the advancement of the 17 general goals established by the UN Sustainable Development Goals (United Nations, 2017).

The societal impact should not be confused with disseminating and transferring research results (Van den Besselaar et al., 2018). Dissemination occurs when research results are made known to the scientific community, policymakers, stakeholders, or the general public. Knowledge transfer occurs when policymakers and social agents use published and disseminated results as a basis for their policies or actions, regardless of whether they have evidence of social improvements.

The evaluation of the societal impact of science is a fundamental aspect to incorporate citizen demands and respond to them from science and social institutions (Reale et al., 2018). In recent years projects such as IMPACT-EV (Sordé Martí et al., 2020) have made progress in the significant challenges of assessing the societal impact of science. Success stories of societal impact show that one of the key elements shared by these research projects has been

citizens' involvement in their development (De Silva & Wright, 2019; Stier & Smit, 2021; Van den Besselaar et al., 2018).

### **Engaging Citizens in Scientific Co-creation Processes**

The report “Monitoring the Impact of EU Framework Programmes” (Van den Besselaar et al., 2018) identifies citizen involvement as one of the four keyways to achieve societal impact. This participation can occur through various means and at different project stages. Moreover, these co-creation processes can occur through the participation of very different social agents such as social entities, associations, companies, or spin-offs, among others (European Commission, 2020). In this article, we use the term co-creation along with this broad perspective.

The idea of fostering citizen participation in science is not new. Areas of knowledge such as the natural sciences show a long history (Miller-Rushing et al., 2012; Sordé et al., 2021). For example, as early as the 17th century, some experiences were identified in which amateur researchers involved non-experts in collecting data based on observations of natural life. These collaborations helped to generate extensive databases and collections of animals, plants, and minerals essential for advancing various disciplines (Cohn, 2008).

The development of enabling technologies has transformed this tradition of science/citizen collaboration based on data collection (Bonney et al., 2016). In this line, growing crowdsourcing has been generated by collecting data via mobile applications in areas such as health, observation of protected animal species or the classification of galaxy images, among others (Chrisinger & King, 2018; Kelling et al., 2019). Such crowdsourcing also promotes the generation and use of open access "big data" (Silvertown, 2009).

In recent decades, several studies have identified a shift towards public participation in science. It would go beyond involving citizens in data collection, encouraging their participation in decision-making, and considering them a source of collective wisdom and innovation (Kozinets et al., 2008; Woolley et al., 2016). In this line, the contributions made by Ala Irwin (1995), who coined the term *citizen science*, stand out. Irwin's work proposes the need to promote grassroots strategies that make it possible to respond to the real needs of social agents through scientific research. For

Bonney et al. (2009), citizen science involves involving social agents in scientific research with a dual purpose: to contribute to the advancement of research and citizens' understanding of scientific progress. Taking up contributions such as those mentioned above, the European Commission (2020) has included the citizen science perspective in its research programme to democratise science, build trust in science, and include collective intelligence in research and innovation.

Despite the clear benefits demonstrated, there are currently essential limitations to involving diverse societal actors in co-creation (Druschke & Seltzer, 2012; Munté, et al., 2011). For example, the people who tend to participate in these initiatives are usually Caucasian adults with high socio-educational levels. Therefore, one of the main challenges will be identifying strategies involving vulnerable groups (e.g., low socioeconomic background, ethnic and religious minorities, or people with disabilities) in scientific co-creation processes. In addition, it will be necessary to develop training strategies and establish effective communication channels capable of fostering it (European Union, 2020).

## **Methodology**

This study has focused on analysing the co-creation processes established in research projects that have demonstrated societal impact. Specifically, the analysis focused on projects belonging to three areas of knowledge: social sciences, humanities, and engineering. The research techniques used included qualitative analysis of three webinars on the societal impact of science and four meetings with members of the Net4Impact research network. In addition, a Communicative Content Analysis of documentation related to the selected scientific projects was carried out (Pulido et al., 2020).

The Webinars have involved 16 speakers from 10 research organisations and institutions located in Spain, Italy and USA. They belonged to different disciplines: Social Sciences (N=3) from three specialities (Pedagogy, Sociology and Law); Humanities (N=10) from four specialities (Ancient and Medieval History; Archaeology; History and History of Art, and Human Paleoecology and Social Evolution), and Engineering (N=3) belonging to the area of Electronic Technology. The participants held different positions in their respective organisations (e.g., Full professor, Associate professor, junior

researchers, transfer technicians or companies' staff). During these sessions, the speakers presented the societal impact of their projects and established discussions among themselves and with the virtual attendees of the three Webinars (N=177).

On the other hand, the examples of societal impacts and co-creation processes presented in the Webinars were analysed and discussed in four virtual meetings. Six members of the Net4Impact network from five areas of knowledge participated (social sciences, humanities, mathematics, environmental sciences, and engineering). The Webinars and the meetings were recorded with the Zoom© videoconferencing platform, the same one used for the virtual meetings. The attendees gave their consent to the recording and subsequent use of the material.

Thirdly, the meetings and Webinars allowed us to identify six projects that had demonstrated a significant societal impact in social sciences, humanities, and engineering. The societal impact analysis of these projects was carried out through specific evaluation instruments designed by the Net4Impact Network. We carried out a Communicative Content Analysis of the project's documentation (Pulido et al., 2020). Through the Communicative Content Analysis, the researchers not only analysed the impact of the projects but also discussed the results of this analysis among the Net4Impact researchers. In other words, the content analysis did not depend on the interpretation of a single researcher. However, the debates established around the analyses made it possible to generate collective interpretations and go deeper into evaluating the societal impact of the projects and the particularities of the co-creation processes in each of the scientific areas.

## **Data Analysis**

The data analysis was carried out through the design of matrix analysis. Three categories of analysis were established: 1) societal impact achieved; 2) agents involved in the co-creation process; and 3) characteristics of the co-creation processes. These categories were established deductively from the review of scientific literature. Among the contributions reviewed, the research team agreed that these three categories allowed the analysis of central aspects of our object of study: the co-creation processes present in research projects that have demonstrated societal impact.

The communicative methodology on which this article is grounded analysis both exclusionary and transformative dimensions (Pulido et al., 2020). It focuses on those aspects that contribute to overcoming the social problems studied (transformative dimensions) and those that contribute to maintaining them (exclusionary dimensions). However, this article has focused only on the transformative dimension of the co-creation processes studied.

Firstly, the *societal impact achieved* category focused on identifying evidence of the societal impact of research projects in social sciences, humanities, and engineering. The definition of societal impact from which we have started is related to the one outlined in previous sections: it occurs when published and disseminated research results, which have been transferred, lead to an improvement concerning agreed and prioritised objectives in our societies (Aiello et al., 2021; Van den Besselaar et al., 2018). Specifically, we have considered the improvements evidenced by the projects about the UN Sustainable Development Goals.

Secondly, the *agent's involved* category included information regarding the stakeholders included in the co-creation processes (Conrad & Hilchey, 2010). We focused on identifying their profiles, diversity, and the processes' capacity to include different views on the topic under investigation.

Finally, the category *characteristics* has considered several relevant elements in the co-creation processes. For example, we have considered the strategies or perspectives that have enabled a central and sustained collaboration, the type of participation achieved, or the use given by researchers to the contributions made by stakeholders (Druschke & Seltzer, 2012; Freitag & Pfeffer, 2013; Gallo & Waitt, 2011; Rock et al., 2018).

Next, we provide the main results obtained by the research. These focus on analysing co-creation processes developed by six projects that have demonstrated societal impact in social sciences, humanities, and engineering.

## Results

### Co-creation in Social Sciences

#### Societal impact achieved and agents involved

By analysing the data obtained in social sciences, two projects have been selected that have stood out for the societal impact achieved. These are 1) the project of the 5th Framework Programme of the European Commission WORKALO (2001-2004), and 2) the project Gender Violence in Universities (2004-2007) financed by the Spanish Ministry of Women's Affairs. The two projects have in common the use of the communicative methodology as a central strategy to establish co-creation processes. In addition, the projects have involved vulnerable groups in their co-creation processes.

Firstly, the WORKALO project has aimed to define innovative strategies for social and economic development oriented towards social cohesion, considering that ethnic minorities and the Roma community, in particular, have a lot to contribute to the reinforcement of social cohesion in Europe. The joint work of researchers, grassroots representatives of the Roma community, activists, associations, and policymakers throughout the project resulted in a relevant policy impact (Aiello et al., 2013). In this sense, the project promoted the recognition of the situations of exclusion suffered by the Roma people and their recognition as a cultural minority by the European Parliament (2005), the Spanish Parliament (2005) and the Catalan Parliament (2001). This legislative advance has led to the development of numerous recommendations and political initiatives in favour of the inclusion of the Romany population, transforming the European, state, regional and local framework of numerous public policies designed for this community. The societal impact derived from these advances has been identified mainly in the educational and employment areas (García-Espinel et al., 2019). For example, the Catalan Government's Comprehensive Plan for the Roma People has reduced school absenteeism and a significant increase in educational results in schools with a high proportion of Roma students. In addition, it has increased the number of Roma people accessing university studies through university access for over-25s (Departament de Treball. Afers Socials i Famílies, 2018).

Secondly, the project Gender Violence in Universities was a pioneering research project. Until 2005, no research on violence against women had explicitly addressed violence against women in Spanish universities (Puigvert et al., 2019; Valls et al., 2016). The project aimed to study gender-based violence in different Spanish universities and analyse what measures were being implemented against it in the university context. The project involved a broad base of social agents, including survivors of gender-based violence, university faculty and students, university service staff, university officials and politicians. This research has had a meaningful political impact that was concretised in two laws of 2007, which rectify the error of the Organic Law 1/2004, of the 28th of December, on Comprehensive Protection Measures against Gender Violence, that does not include universities and workplace as spaces where gender violence also occurs. This study demonstrated the existence of the problem at universities and analysed the effective measures conducted in other countries. Concretely, one of the main impacts derived was the creation of specific offices with protocols against sexual harassment in Spanish universities based on the practices of universities that were considered the most effective in this regard worldwide. In addition, the study favoured the replication of solidarity networks with survivors of gender-based violence in universities (Puigvert et al., 2019; Vidu, 2017), an initiative that had demonstrated a substantial impact on the support and accompaniment of victims. Finally, the project also set a precedent for creating new legislative frameworks that protect people supporting the victims. It would be the case for recent developments in the field of Isolating Gender Violence (Flecha, 2021; Vidu et al., 2021).

### **Implications of the co-creation processes**

The capacity of Communicative Methodology (CM) to enhance co-creation processes involving groups traditionally excluded from research (e.g., cultural minorities or survivors of gender-based violence) has been widely studied (Gómez et al., 2019; López de Aguilera et al., 2021; Racionero et al., 2021). CM promotes societal impact by involving people or communities in all phases of the research (from the beginning to the end of the research). Furthermore, the objective of CM goes beyond the diagnosis of situations of

inequality, identifying those elements that lead to overcoming the problems studied. This orientation facilitates the societal impact of the research.

CM enhances the potential of traditionally excluded stakeholders' participation through egalitarian dialogue. Meanings are constructed through the interactions between researchers and stakeholders. Therefore, a central element is constructing a dialogical relationship between all agents involved in the co-creation process, based on egalitarian participation and intersubjectivity. It implies breaking the epistemological gap between research staff and participants. In this dialogical relationship, researchers share their accumulated scientific knowledge with stakeholders while stakeholders contribute their knowledge about the lifeworld (AIELLO *et al.*, 2013). This dialogic relationship also facilitates stakeholders to co-lead the research, encouraging them to take central roles in recreating actions based on scientific knowledge in their context (MUNTÉ *et al.*, 2011).

CM promotes methodological innovations built on international scientific literature published in JCR journals (LÓPEZ DE AGUILETA *et al.*, 2021). Some distinctive elements of CM are the communicative organisation of research, communicative data collection techniques, or communicative data analysis (GARCÍA-YESTE, 2014). All of them imply establishing co-creation processes sustained over time with vulnerable groups. For example, the advisory board or multicultural research teams help avoid prejudices and stereotypes in social science research by including vulnerable groups in scientific creation through direct participation. It also facilitates a constant dialogue between research staff and community representatives.

## **Co-creation in Humanities**

### **Societal impact achieved and actors involved**

In Humanities, the data analysis has allowed us to identify co-creation processes present in two projects, both of which have demonstrated a previous societal impact: 1) the palaeontological site of Camp dels Ninots and 2) the Tarraco Viva Archaeology Festival.

The project at the Camp dels Ninots site in Caldes de Malavella (Catalonia, Spain), underway since 2003, has been developed by the Catalan Institute of Human Paleoecology and Social Evolution (IPHES-CERCA). It is uncovering

a continuous sedimentary sequence filling an ancient lake inside a volcano *maar* type that allows inferring relevant data for the knowledge of the European climatic, landscape and faunal evolution. The project has generated a corpus of data at a scientific level, previously non-existent. It has allowed the characterisation of the paleoclimate, flora, fauna, and geology of the Upper Pliocene Age (Gómez de Soler et al., 2012; Jiménez-Moreno et al., 2013). A very important period for being at the gates of the Quaternary (emergence of the genus *Homo* in Africa) with a great environmental and evolutionary implications (transition from subtropical climate to glacial-interglacial dynamics that conditioned the extinction and the emergence of new mammal faunas), and with temperatures similar to those projected for the end of this century that can help us to understand climate change on a local and global scale. Furthermore, its valorisation as a unique heritage site through its Declaration of National Cultural Heritage (BCIN) (Generalitat de Catalunya, 2015).

The co-creation processes established during the almost 20 years of project development have involved more than 30 researchers from 14 European public research organisations. In addition, public administrations, social and cultural entities, companies, and the educational community of the territory have participated, all of which have contributed to the project's societal impact.

Between the impacts identified, the project has helped increase social awareness concerning the meanings and values of heritage and the implementation of sustainable management strategies related to the social and economic development of the territory.

The local awareness in relation to the site's heritage values is also demonstrated by multiple actions by social and cultural entities such as popular bestiary, Ninots nursery, traditional music "sardana" of the Camp dels Ninots, among others.

In this sense, the project has generated an ongoing demand for educational programmes that include the knowledge generated by the Camp dels Ninots in primary and secondary schools. Between 2014 and 2021, for instance, around 7600 students participated in the scientific education programmes organised by IPHES-CERCA that included contents from the project (Evoluciona, 2021).

In addition, based on the knowledge generated by the site, the creation of cultural and tourist facilities with the *Espai Aequae* and the circular itinerary around the site in the municipality of Caldes de Malavella has been promoted ([Ajuntament de Caldes de Malavella, 2020](#)). These facilities have generated direct and indirect jobs and contributed to the local tourist offer.

The second example stems from the need to involve citizens in the understanding, enjoyment, and recreation of the monumental heritage of Tarragona (Spain). Since the 19th century, a considerable accumulation of scientific data has been generated on the Roman past of the city, considered a World Heritage Site by UNESCO ([Aquilué et al., 1991](#)). However, the critical challenge was to achieve citizens could understand and participate in the city's cultural wealth.

The Tarraco Viva Roman Festival was born in 1999 to democratise the historical knowledge provided by this heritage. To this end, the festival organised and developed a wide range of activities to disseminate knowledge of ancient history and to be able to provide the public with tools for reflection on the historical past. These include historical reconstruction shows, guided visits to monuments understood as small theatre plays, or ancient culture recovery through music, gastronomy, or street markets. These activities are carried out in significant settings such as ancient walls, temples, amphitheatres, circuses, or aqueducts.

Concerning co-creation processes, the Tarraco Viva festival has promoted the emergence of re-enactment groups ([Gapps, 2009](#)), living history and experimental archaeology in which citizens play a central role. For example, eight historical reconstruction groups have been created in Tarragona, which meets every year at the festival with other European historical reconstruction groups. These groups, made up of citizens of all ages, organise to rigorously document themselves and faithfully reconstruct archaeological objects, battles, or ceremonies. They often include history buffs, historians, and archaeologists who co-create the knowledge necessary to carry out the re-enactments with the group members. Thanks to the seriousness within the groups, they are a valuable dissemination strategy that regularly collaborates with museums, archaeological sites, and historical sites ([Ruiz de Arbulo Melian, 2014](#)). In this way, the citizens themselves are dedicated to faithfully reconstructing different aspects of Roman society and the Roman army and presenting them to the public playfully and understandably.

### **Implications of the co-creation processes**

An increase in social awareness has been identified in the co-creation process in relation to the conservation and preservation of natural and cultural heritage. Knowledge of the ecosystems of the past and the implications that climate change has had on them over time makes today's society more aware of the necessity to preserve the natural heritage and generate positive attitudes in their daily activities.

The use of disciplines based on communication systems, such as heritage interpretation, has proven to be the most appropriate way to transform scientific language into an understandable language to society. At the same time, this interpretative dialogue between the scientific community and society is the key to generating social impact. The guiding principle of effective interpretation is “through interpretation, understanding; through understanding, appreciation; through appreciation, protection” (Tilden, 1957).

For this dialogue to be effective and to define a strategic plan based on heritage, identity and development criteria, the collaboration between academia, public administration, social and cultural entities, and private enterprise is needed.

One of the aspects observed that has a greatest impact on the heritage values is the educational community. Awareness and involvement through education and interpretation is certainly a key part of the conservation of natural and cultural heritage and the increase in heritage knowledge. Finally, another aspect observed is that the tourist transformation of the natural and cultural heritage, based on sustainability criteria, contributes actively to the social and economic development of the territory. Museographic equipment based on an interpretative dialogue offers the public authentic experiences and contributes to the wealth of the local economy.

Strategies such as re-enactment (Gapps, 2009) have also been identified, which have enabled increasingly democratic access to knowledge about history and heritage. Practices such as re-enactment have contributed to scientific knowledge being placed at the service of cultural practices that offer participants and audiences authentic experiences and representations of history. Unlike the transmission of historical knowledge through monuments and museums, re-enactments have involved citizens actively in the pursuit of

scientific knowledge and close collaborations with researchers and specialists. One of the keys to re-enactment is the search for the authenticity of the historical chapter recreated, and therefore it is the participants themselves who engage in rigorous research. For example, when re-enacting, participants research historical characters and portray them accurately with the help of photographs, diaries, and letters. In addition, re-enactment inspires people to read other performances critically and to have a deeper understanding of history.

In the case of the Camp dels Ninots, the hyper-realistic recreation of sculptures of different animals located in the site, together with a series of interpretative panels explaining different elements of the site (geology, fauna, flora, working methods, history of research, etc.) has contributed significantly to the understanding of the heritage by the citizens.

## **Co-creation in Engineering**

### **Societal impact achieved and agents involved**

During this research, two cases of co-creation identified in the field of engineering have been selected: 1) the collaboration between the Group of Power Electronics and Microelectronics (GEMP) of the University of Zaragoza and the Bosch and Siemens Home Appliances Group (BSH) and 2) the co-creation processes established within the framework of the project “Silicon carbide power electronics technology for efficient devices” (SPEED) of the 7th Framework Programme of the European Commission. These cases have illustrated how successful collaboration between universities and companies can benefit when facing the growing complexity of scientific-technical problems. For instance, by bringing together multidisciplinary perspectives, responding to the increasing need for human and material resources, the demands of speed imposed by the market or the need to achieve more significant economic and societal impact through research (Boardman et al., 2012). Specifically, the two cases selected allow us to identify how these co-creation processes represent a *win-win* for both research organisations and companies.

Firstly, the co-creation processes established over 30 years of uninterrupted bilateral collaboration between GEMP of the University of

Zaragoza and the BSH group stand out. As a result of this collaboration, the University of Zaragoza has positioned itself as one of the most prolific scientific research institutions in household appliances (Thomson Reuters, 2016) and the BSH Group as the first in Spain and one of the first in Europe to register patents (Serenó, 2019). The technological developments derived from this collaboration have resulted in 10 generations of induction appliances and 13 million units sold in international markets (Lucía et al., 2013). All of them have been manufactured in Zaragoza by creating 400 different appliance models. This production has generated a substantial social and economic impact on the community. For example, the growing manufacture of household appliances has generated 1500 direct and indirect jobs in R&D, companies belonging to the BSH group, and auxiliary companies in the surrounding area that support production. In addition, the direct involvement of the BSH group in the University of Zaragoza has improved the education of students for the real world (Lucia et al., 2012).

Secondly, the SPEED project has established university/industry co-creation processes, leading to the development of more efficient electronic devices (Soler et al., 2017). The collaboration between a consortium of universities from 7 European countries (Spain, Switzerland, Italy, Sweden, UK, Germany, and Austria) with several European companies has led to the development of technology around power electronic devices made using silicon carbide (SiC) instead of silicon (Si). The use of SiC electronic devices allows the energy efficiency of power electronic converters to be improved compared to conventional Si devices. It allows for lower energy losses in electrical energy transformations, generating less energy at the source for the same energy needs at the consumer. The co-creation processes established in the project framework have brought energy efficiency benefits to several companies involved in the project. For instance, it has helped Infineon develop a SiC power MOSFET transistors portfolio, which was not available before the project.

### **Implications of the co-creation processes**

The analysis of the data collected has allowed us to identify a series of considerations present in the co-creation processes which have been provided by engineering researchers who have developed projects with societal impact.

These considerations include the relevance for research to contemplate companies' real needs, finding a balance between the necessities of the different parties involved, building relationships of trust or opening collaboration with other community agents. The benefits of researchers being aware of the societal impact generated by their scientific activity have also been identified.

One strategy that has facilitated co-creation and societal impact has been to question the traditional research dynamics based on following only the sequential line: research, development, and innovation. Research from the industrial needs identified by companies has contributed to generating innovations that have provided efficient responses to real problems. These innovations, in turn, have been significant enough to be valued by the market and have contributed to new scientific advances.

Participants in the Webinars and meetings have also highlighted that each actor involved has played a specific role and contributed expertise. Universities and research centres have the time and knowledge to conduct research, and companies know the market but do not have the time to research to respond to their needs. Therefore, both actors can bring mutual benefits to each other. However, companies need to be realistic about the contribution that the university can provide them and be aware of the unforeseen events that can arise in innovation processes.

The need to identify trade-offs between the different objectives that universities and companies may present has also been identified. Sometimes they may have different or conflicting interests. For example, the university may be interested in publishing, and the company needs confidentiality to develop a patent. Therefore, it is necessary to find a balance between the different needs that is satisfactory to both parties. This last consideration is closely related to the need to develop relationships of mutual trust. As mentioned in previous sections, personal relationships are essential to understanding each other's necessities and finding consensus between the different needs.

In addition to trust, engineering researchers have stated participants in the co-creation process must perceive a prioritisation of the joint activity. In other words, they must perceive a committed and sincere dedication from the different actors involved in the jointly developed activity.

The co-creation process can also foster open innovation beyond the university and the company and consider other community actors' roles. For example, companies may receive innovative ideas from university students. Moreover, these students can also be involved in research, advancing scientific knowledge.

Finally, participants in the study have highlighted some implications concerning researchers' role. According to them, researchers must advance scientific knowledge through research and have the necessary knowledge to apply it in authentic contexts. Furthermore, when the research team can measure and be aware of the societal benefits generated by their scientific activity, it brings them a sense of pride and transcendence regarding their research task.

## **Discussion and Conclusion**

In this article, we have analysed co-creation processes established by research projects that have been shown to generate societal impact. It builds on previous contributions, which have seen how specific co-creation and citizen science initiatives have not only promoted better scientific advances but can also have a positive impact on the lives of the people involved in these processes (Evans et al., 2005; Freitag & Pfeffer, 2013; Irwin, 1995). It has implied adopting participatory approaches that go beyond a merely instrumental involvement of citizenship (e.g., contemplating citizens solely as data collectors or providers) to paradigms that perceive social actors as sources of knowledge and innovation (Kozinets, Hemetsberger & Schau, 2008; Woolley et al., 2016). Experiences that have adopted these perspectives have adequately cultivated participation, involving citizens actively in the design, implementation, or applications of research findings (Druschke & Seltzer, 2012).

Despite the reported benefits, we have also collected a growing number of contributions analysing failed attempts at co-creation (Freitag & Pfeffer, 2013). Among the main challenges, they identify the need to identify methodologies and strategies that enhance co-creation processes or to involve groups that have traditionally been excluded from scientific creation in co-creation (Druschke & Seltzer, 2012; Rock et al., 2018).

Instead of focusing on failures in this article, we have analysed success stories. Thus, we have provided examples of six projects that have achieved societal impact. They have included co-creation processes involving different social agents (e.g., general population, cultural minorities, survivors of gender-based violence, educational community, companies, or policymakers, among others). Our analysis has also shown that co-creation is not a one-way street but that different strategies and perspectives can be adopted to promote it.

The projects analysed in the social sciences have established co-creation processes in which they have managed to involve vulnerable groups through the implementation of communicative methodology (CM) (Gómez et al., 2019; López de Aguilera et al., 2021; Racionero-Plaza et al., 2021). Through methodological innovations such as the advisory board or multicultural research groups, it has been possible to reduce the participatory gap between researchers and vulnerable groups (Bonney, et al., 2009). Thus, the egalitarian participation of groups such as the Roma community or survivors of gender-based violence in creating scientific knowledge has been promoted. Egalitarian dialogue and participation promoted by CM has also stood out for involving participants in research co-leadership processes. Vulnerable groups are vital agents in recreating research results in their contexts to address critical social challenges (Aiello et al., 2013; Munté et al., 2011).

The selected experiences in the field of Humanities have highlighted the importance of planning the heritage valorisation processes of archaeological sites and evaluating participatory and co-creation processes. In this sense, implementing museum facilities based on the knowledge derived from the development of archaeological projects can produce a high societal impact. These kinds of facilities can contribute to the social and economic development of the territory, acting as a pole of attraction for cultural tourism.

Planning and scheduling educational activities derived from the knowledge provided by scientific advances in palaeontology has been identified as a critical element. These initiatives have involved science educators who have made palaeontology more easily understandable for the local community and school population (Druschke & Seltzer, 2012). In addition, through initiatives such as re-enactment, historical reconstruction groups have emerged. Citizens have teamed up with experts to research

chapters of history that they intend to recreate (Ruiz de Arbulo Melian, 2014; Gapps, 2009). In this way, citizens have taken leading roles in disseminating knowledge about history and cultural heritage.

Lessons learned in engineering have illustrated various typologies of successful co-creation processes between research organisations, universities, and companies. These collaborations have brought mutual benefits to all parties involved in this sense. It has been shown that considering companies real needs can be an essential element for research to provide more innovative and sustainable technologies (Soler et al., 2017). These co-creation initiatives can generate a social and economic impact on the community, for example, concerning the generation of employment or increased competitiveness of companies. The positive impact on companies can also benefit the research organisations and universities that have generated it. For instance, researchers can collect societal impacts in academic publications, increasing their scientific impact. Furthermore, they can increase the quality of their teaching by bringing university students closer to successful experiences promoted in the real world (Lucia et al., 2012).

Finally, it is worth noting some limitations and prospective this study provides. The projects selected and analysed in this article represent a small sample of the successful examples identified by the Net4Impact Network. The analysis of a larger sample of projects will provide us with further results and enrich the contributions currently made. This article also raises important future research directions. For example, it shows the need to expand existing theoretical and practical knowledge on how researchers conceive, plan, develop and evaluate co-creation processes to increase research's social impact.

## Notes

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