Countering science skepticism by means of citizen science – The ultimate solution?

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DOI 10.3217/978-3-85125-976-6-01

Abstract. Research suggests that citizen science can improve the relationship between science and society. Citizens are involved in one or several steps in the academic research process, and sometimes also in decision-making. In addition to the effects found previously, such as increasing public understanding of science and the acquisition of subject-specific knowledge and methodological skills among participants, the question still remains whether citizen science can counter science skepticism. Based on a qualitative comparative analysis of literature, the potential of citizen science to counter science skepticism is discussed. After examining the promises of citizen science and general measures to alleviate science skepticism, the role and challenges of citizen science projects are investigated along the lines of changes in attitude, psychological effects, the role of participation and the importance of (science) communication as well as the benefits for the participants. The results show that citizen science can help counter science skepticism in several respects in addition to the role of (science) communication. While these findings need to be confirmed by empirical research, they still provide a basis for the discourse on the relationship between science and society and the role of citizen science in combating science skepticism in Europe.

Keywords: science-society relationship, participatory research, community research, value, academia

1 Introduction

Science enjoys high popularity, also in the public discourse. The coronavirus pandemic has highlighted this fact. During the pandemic, experts were not only visible in traditional media but also informed policymaking. However, the pandemic also revealed the science skepticism among the general public who did not trust the information provided by scientists and the government (Rutjens et al. 2021).

Nevertheless, also before the pandemic, science has been part of public discourse in which light is shed on the responsibilities of academic institutions and researchers towards society, including policy, economy and social issues. Policies and measures are regulating academic research and innovation. Other issues that academia is confronted with are anti-scientism movements rejecting the outcomes of academic research (Bucchi 2004, 1), as well as science skepticism.

Science in Europe dates back to the 17th century. This period was characterized by the scientific revolution, which itself was defined by the use of distinct procedures for engaging in science, including experimentation, the non-hierarchical nature of knowledge, i.e. that scientists engage in analysis and not relying solely on the writings of previous scholars, a constantly developing methodological repertoire for studying nature and the significance of exchanging knowledge (Bucchi 2004, 11).

As science developed, so did its institutionalization and the formation of a social group, i.e. the scientists, who formed rules within their community and gained social status (Bucchi 2004, 12). This process of professionalization and institutionalization created a social subsystem for science (Bucchi 2004, 14). This subsystem was also endowed with a certain prestige to which knowledge and wisdom was attributed. This attribution of knowledge has relations to the deficit model (Layton 1993), which was prevailing in science communication for some time. It states that the public has a knowledge deficit and needs to be educated by knowledgeable scholars.

Science education and scientific literacy emerged from this idea. Scientific literacy includes knowledge of facts of science, knowledge of the methods used in science and an appreciation of the scientific outcomes, while not resorting to opinions or superstition (Bauer 2009, 223). However, academics have often put too much emphasis on the knowledge, i.e. facts that science produced and not so much on the methods on which it is relying. Scientific literacy thus especially includes knowledge of the academic process, the uncertainty involved, controversies led and the replication of results (Bauer 2009, 223).

1.1 Citizen science

1.1.1 Definition of citizen science

Citizen science describes the involvement of members of the public, who are non-professional researchers in the related field into academic research (Haklay et al. 2021, 14). Since citizen science plays a decisive role in European funding strategies, the definition of the European Union is given here: “Citizen science can be described as the voluntary participation of non-professional scientists in research and innovation at different stages of the process and at different levels of engagement, from shaping

research agendas and policies, to gathering, processing and analyzing data, and assessing the outcomes of research" (European Commission and Directorate-General for Research and Innovation 2020, 1).

This reference shows that participants may be engaged in different research steps, ranging from data collection, data analysis to the publication and dissemination of the results. Typical examples can be found in the natural sciences, where members of the public are, for example, reporting their sightings of wild animals in urban environments by means of an app (Walter and Zink 2017) or they are taking and analyzing freshwater samples (Strobl et al. 2019), or they might also be co-authors of academic publications (Guerrini et al. 2019). However, citizen science does not only enjoy popularity within the natural sciences (Frigerio et al. 2021), but is gaining ground in other fields of academic research as well, including health science (Wiggins and Wilbanks 2019) (where participants collect their health data or contribute their experiences, among others), social sciences (Albert et al. 2021) (that look back on a long tradition of participatory research anyhow), the humanities (Heinisch et al. 2021) , in which citizen science was also already practiced before the advent of the term 'citizen science'.

The primary objective of many citizen science projects is the advancement of knowledge about a certain topic or field. Other, broader objectives of citizen science projects might be social change, an enhanced relationship between science and society, or a higher degree of public understanding of science among the general public. For this, citizen science projects need to adjust the project design, the measurement of outcomes, engage new groups of people and open up new trajectories for research (Bonney et al. 2016).

The range of activities in which citizens can be involved in academic research is broad, ranging from microtasks (within the meaning of crowd-sourcing being characterized by a large number of people contributing a small share to the overall project, such as classifying images, in which every participant completes small, clearly defined tasks), broader tasks, such as annotating text that require additional subject-specific knowledge to the entire co-creation (Bonney et al. 2009) of a research project from scratch with academics. Participants in citizen science projects are therefore involved in e.g. data collection, data analysis, playing games and preparing evidence for policymakers.

1.1.2 Approaches to citizen science

Due to the increasing popularity of citizen science in many disciplines, it is important to distinguish between citizen science and other forms of public engagement in science. The European Union has a broad understanding of public engagement in science. While linking it to Responsible Research and Innovation (RRI), the European Commission emphasizes the role of public engagement to create a livable and desirable future for

everyone with regard to science and technology and to include as a diverse range of actors as possible in science and technology development (European Commission 2020).

Other authors (Martin 2017, 143–144) differentiate between public engagement and public participation in science. While public participation in scientific research contributes to the advancement of academic knowledge, public engagement in science might rather focus on science communication (Martin 2017, 143–144).

Another differentiation worth mentioning is the difference between citizen science and community science. Community science, civic science or community-driven science is usually initiated and guided by a certain community (Haklay 2015, 15), who might approach academic researchers to help them to tackle a certain issue. In comparison, citizen science is generally understood as a researcher-driven academic endeavor, for which a researcher has a certain topic or research question in mind and requires the support of members of the public to address this question. Nevertheless, the boundaries between these approaches are often blurred. In this study, however, the term ‘citizen science’ will be used to describe the engagement of members of the public in academic research that is initiated and driven by academic researchers.

2.1 Science skepticism

2.1.1 Definition of science skepticism

Different terms are used to denote negative attitudes towards science covering a broad spectrum of constructive criticism to a general rejection of the academic system (Peters et al. 2023). Often, science skepticism has a negative connotation referring to its destructive nature, as the definition by Rutjens et al. (2022, 102) shows: Science skepticism is the “[s]ystematic and unwarranted rejection of science”.

Other terms used to denote negative attitudes towards science are science criticism, distrust of science, science-related populism, or science denial, among others, which are often used interchangeably with science skepticism. For Peters et al. (2023), the distinguishing characteristics of science skepticism are that science skepticism is usually related to general distrust in science and can relate to skepticism towards certain theories or to the general rejection of science or its methods. Whether science skepticists are generally open towards science is unclear (Peters et al. 2023). Although skepticism can also have a positive connotation related to legitimate skepticism, in this article, the definition by Rutjens et al. (2022) given above is used.

Science skepticism is dynamic which is also illustrated by the fact that skeptical attitudes often depend on the relevant scientific topic. For example, in some regions, climate

change skepticism correlates with political conservatism or vaccine skepticism with scientific literacy and spirituality (Rutjens et al. 2022, 102).

Although skepticism is often framed rather negatively, it is also an inherent element of science itself.

2.1.2 Legitimate skepticism

Skepticism, especially organized skepticism (Merton 1957, 646) is an important element of academic enquiry, i.e. a value in science. Researchers should engage in skeptical behavior and "be critical of [their] own practice" (Normand 2008, 47). Skepticism is also part of legitimate debate since "organized skepticism and open critical discourse are essential features of science and of a democratic society" (Starkbaum et al. 2023, 2).

2.1.3 Attitudes towards science and science skepticism in Europe

The overall sentiment in Europe towards science is a positive one. A Eurobarometer survey showed that almost 90% of the citizens in the European Union consider the influence of science on the European society a positive one. Especially certain technologies are believed to improve the way of life. Nevertheless, the Eurobarometer respondents do not think that everybody in the European Union benefits equally from the developments in the fields of science and technology. More than half of the respondents stated that science and technology benefits only those who are already privileged and almost one quarter believes that the needs of women and men are not taken into account equally. The respondents have a positive perception of scientists since they associate intelligence, reliability and collaboration with them. However, almost 70% of the surveyed EU citizens stated that they are in favor of more evidence-based decision-making in the field of politics. Here, they see it as the scientists' responsibility to intervene. Regarding the involvement of members of the public in academic research, which has a clear relation to citizen science, 61% approve this idea in order to generate science and technology meeting the values and needs of members of the public (European Commission 2021). In the Eurobarometer 2021 survey, science skepticism is assessed by the relevance of science in the everyday life of the respondents or the contribution of science to future prosperity (Starkbaum et al. 2023, 2).

A survey addressing the situation in Austria draws a similar picture, but only to a limited extent. Although Austrians are quite skeptical about science, more than half of them are interested in academic knowledge and academic research. For two thirds, information about academic research is important, but only 37% think that they are well-informed. One third does not really trust science. 37% rather trust their common sense instead of academic findings. The respondents expressed criticism of science as they assume a strong influence of politics and business on academia. Persons who did not experience

a certain degree of education are twice as likely to be skeptical towards academic knowledge and academia. Nevertheless, and similar to the results of the Eurobarometer study, the majority of the respondents think that academics are qualified and competent. However, the respondents also believe that in an open society, it should be allowed to scrutinize everything, and even question science (ÖAW 2022; Starkbaum et al. 2023, 2).

2.1.4 Reasons for science skepticism

Science skepticism is not a uniform phenomenon. It is rather characterized by heterogeneity. Rutjens et al. (2022, 102) spot three different factors contributing to this heterogeneity: The predictors of science skepticism, the domains of science skepticism and cultural differences. Skepticism depends on ideologies and beliefs. Furthermore, there are differences in skepticism between domains, e.g. climate change or genetic modification. Furthermore, cultural differences can explain the variety of attitudes and beliefs related to science skepticism. Therefore, there is a variation of science skeptical attitudes in different countries, regions and depending on the scientific topic, such as climate change, vaccinations or genetic engineering (Rutjens et al. 2022, 102). An important indicator for negative attitudes towards science is mistrust in science (Peters et al. 2023, 10).

In contrast to science skepticism, which is rather heterogenous, science denial is a homogenous phenomenon: Regardless of the scientific information or fact that is provided, there is denial. Scientists may even face attacks, either in the professional or private realm. In addition, denial is often politically motivated (Lewandowsky et al. 2016, 538).

Starkbaum et al. (2023, 5) identify eight factors of science (and democracy) skepticism in Austria, including the framing of skepticism itself (i.e. any criticism is considered skepticism), the circumstance that citizens do not see the presence of science in their lives, the fact that criticism of science is present in all societal groups, the interrelation between criticism of science and criticism of democracy, the low level of science communication and reflection within academia (referring to contradictory results or the influence of interests on academia), changes in the public sphere and media challenging the function of science in society as well as Austria’s relationship to science throughout history.

2 Method

The overarching research question is: How can citizen science decrease science skepticism in European societies? Answering this research question is important because citizen science is enjoying increasing popularity. In addition, many stakeholders, including researchers engaging in citizen science, citizen science networks, funding bodies and governmental organizations are claiming a plethora of promises of citizen science. These promises include, among others, an improved relationship between science and society (‘operationalized’ as, e.g. enhancing the trust between science and society and reducing science skepticism). Therefore, the aim of the article is to find evidence for these claims in the literature with a focus on citizen science as a means to counter science skepticism and discuss the resulting implications for citizen science practice. For this, a literature review and qualitative comparative analysis were conducted. Literature was searched on Web of Knowledge (April 2023) by using a combination of the keywords “citizen science” and “science skepticism”, including different language variants. Additional key words were used to replace “citizen science” (“crowd science”, “community* science”, “participatory science”). After assessing the resulting 123 titles and abstracts for their suitability to answer the research question, especially if they had a clear relation to citizen science (and not science overall), the publications were categorized according to the following topics: General suggestions to counter science skepticism, promises of citizen science (for countering science skepticism), challenges of citizen science (especially those related to increasing science skepticism) and concrete measures or effects of citizen science. The core findings related to the activities, framework conditions and benefits are presented in the following sections.

3 Results

3.1 Promises of citizen science

The promises citizen science holds are, among others, that it increases the public understanding of science (Bonney et al. 2016), that participants acquire disciplinary knowledge and competences for scientific reasoning (Pandya et al. 2018), and more generally, to improve the relationship between science and society (Franzen 2019). Citizen science can also achieve greater impact, for example, by reaching the Sustainable Development Goals (Fritz et al. 2019) and thus contribute to a greater good. Also, the European Commission is highly supportive of citizen science as it considers citizen science a means to strengthen society’s trust in science through interaction between citizens and academic researchers. As such, citizen science, according to the

European Commission, may enhance the effectiveness and relevance of research and innovation, improve quality and creativity, make research and innovation more transparent, and increase the public's confidence in research (European Commission and Directorate-General for Research and Innovation 2020, 1).

3.2 Living up to promises

The European Citizen Science Association (ECSA) highlights the knowledge gain achieved through citizen science. Other authors consider citizen science entangled in the push for the democratization of science (Irwin 1995) on the one hand, and the academic freedom or autonomy of academic researchers, on the other. While public engagement in research and innovation processes should better align the needs and expectations of society with research (Bauer et al. 2021, 343), it may also jeopardize the academic freedom and the autonomy of researchers since full participation in academic research would also mean that non-academics have a say in the decisions on what deserves to be investigated in research (and what does not) (Suomela 2014, 184). Another challenge in citizen science is the extent to which citizens can obtain an insight into academia.

In addition, persons or organizations engaging in or promoting citizen science might have different agendas, ranging from the agenda of the researchers, who may want to advance knowledge in a certain field, the agenda of funding bodies who want to address certain topical issues and the agenda of other stakeholders involved in the process. Depending on the topic and aim of the project, citizen science might involve different participants, such as members of certain communities, municipalities, NGOs or industry who have different priorities as well. While researchers might focus on the advancement of knowledge in collective terms, they are also interested in publishing and presenting their research, thus having rather personal interests. On the other hand, participants might want to improve their environment or social status, for example. Other stakeholders, such as industry representatives might push their business sector and the related interests, while NGOs would rather focus on humanitarian, social and environmental justice and support. Given this variety of interests and expectations, can citizen science remedy science skepticism?

3.2.1 The typical citizen science participants

At the moment, the average participant in citizen science activities is white, male, well-educated and middle-aged (Pateman et al. 2021). Furthermore, studies suggest that there is a male bias in those projects addressing physical science, in online projects and projects fostering competition and roles with high responsibility (Pateman et al. 2021, 3).

This shows that the participants in citizen science are not representative for the entire population. Nevertheless, the citizen science community is aware of this fact and tries to

increase the public engagement of underrepresented groups. Examples of these initiatives include a working group on empowerment, inclusiveness and equity[1] of the European Citizen Science Association, whose mission is to attract more people having different backgrounds to citizen science and to allow these participants to shape projects. This should ensure that citizen science projects have a real-world impact and address the needs and concerns of a wide range of people. Moreover, researchers are addressing the processes in citizen science that lead to the exclusion of certain groups of people. Regarding inclusive and exclusive practices in citizen science, the five factors of exclusion according to Montanari et al. (2021, 3) are discrimination (based on a person's identity), geography (due to the place of residence), governance (related to a person's autonomy in making decisions), socio-economic status (related to income) and, finally, shocks and fragility (a person's vulnerability to risks of any kind). Considering the results from studies addressing science skepticism (Rutjens et al. 2022; Starkbaum et al. 2023), science skepticism can be found in all social groups. Therefore, inclusive citizen science practices can help to engage these groups and provide them with hands-on research experience.

3.2.2 Expectations, interests and benefits

Another challenge is to align the expectations of the participants with the objectives of the project. Especially the participants' motivation might change throughout a citizen science project, as explained above. While researchers might 'just' want to answer a research question, participants might want to see actual impact on their lives or might want to experience a contribution to a greater good.

Therefore, striking a balance between all interests and generating a win-win situation for all the persons involved, appears challenging. For researchers, it is important that they do not only focus on the academic outcomes of a citizen science endeavor, but that they also assess the benefits for the members of the public. From an academic point of view, these benefits might be science education and increasing scientific literacy among the general public. In addition, it may also include raising awareness for an issue and creating enthusiasm for research. From the participant's point of view, the benefits might be completely different, including being part of a community, engaging in dialogue, having their voice heard or influencing policymaking (Riesch and Potter 2014, 108).

Another aspect are the different understandings of citizen science and the different approaches applied to this field. Suomela (2014) differentiates between two views on citizen science. The first is the emancipatory-participative view, which is characterized by the intention to change the relationship between members of the public and academic research and knowledge. The second view is the instrumental-pragmatic, which sees

[1] https://www.ecsa.ngo/working-groups/empowerment-inclusiveness-equity/

citizen science as a means to achieve the goals of academic research. Here, the primary aim is not to change the relationship between science and society but to use citizen science as a method within the toolbox of researchers. These diverging views highlight the possible fields of tension that might arise when the researchers and participants in a citizen science project have a different understanding of the intended outcome, i.e. change in relationship vs advancement of academic knowledge. This again shows the significance of expectation management and clear communication throughout a project. If a citizen science project falls short of the expectations of the participants, a citizen science project can cause more harm than good regarding countering science skepticism and improving the relationship between science and society.

3.2.3 Insight into academia

Generally, the question arises whether citizen science can provide participants with a true research experience and provide a realistic glimpse into science. Some authors argue that citizen science might reduce the entire culture of academia to an academic method alone (Mirowski 2017).

Based on these ambivalent outlooks and before answering the question whether citizen science can serve as a remedy, we first address general measures proposed to counter science skepticism.

3.3 Measures to counter science skepticism

Suggestions for countering science skepticism or science denial are provided by Lewandowsky et al. (2016, 544), who propose three measures, including a) responding to the concerns regarding transparency and questionable practices in research, e.g. by adhering to modern standards of openness; b) bringing activities of politically motivated actors to undermine science to the attention of others and c) “skeptical members of the public must be given the opportunity to engage in scientific debate” (Lewandowsky et al. 2016, 544).

Based on a study in 24 countries, Rutjens et al. (2022) come to the conclusion that science skepticism can be countered by enhancing scientific literacy. However, the effectiveness of increased scientific literacy depends on the cultural context. To be really effective in choosing strategies for countering science skepticism, researchers and communicators need to understand its causes taking into consideration different cultural situations and domains. Moreover, the authors suggest to further investigate the relationship between spirituality and science skepticism. Moreover, an important aspect for the inclination to support science is faith in science (Rutjens et al. 2022, 112).

3.4 Citizen science as remedy for science skepticism?

This section is dedicated to the question whether and how participation in citizen science projects can help to alleviate science skepticism. Acar (2023, 1) argues that citizen science (which they termed crowd science) can counter science skepticism through the psychological impact on both the participants and observers who are not contributing to a citizen science project themselves but are hearing about it. Citizen science is a way to engage members of the public in academic research who can thus influence academic projects themselves.

The results of the aforementioned studies on science skepticism allude to misunderstandings about science among members of the public. This may be related to the opinion that academia is an elite who is working in the ivory tower and not considering the real-world needs of society. Citizen science might therefore be a promising means to open up this ivory tower to non-elites and address actual needs of members of the public. Furthermore, science is often considered as a way to approach the truth and find truth. However, science "is better seen as organized scepticism" (May 2011, 4685). As such, science is a journey that brings along a variety of uncertainties (May 2011, 4685). These uncertainties, and any contradictory academic results might even further increase science skepticism. Nevertheless, science skepticism can be decreased by learning about scientific methods and ways of addressing uncertainty in research and scientific discourse.

3.4.1 Changing attitudes

Learning outcomes found in studies on citizen science projects are a change in attitudes towards science, enhanced knowledge of science as well as the subject at hand and an enhanced understanding of the way science works (Aristeidou and Herodotou 2020, 10). Nevertheless, there is hardly any evidence if these changes result in a more positive attitude towards science and thus, in lower science skepticism. One study on a citizen science project in astronomy (Price and Lee 2013, 773), however, reported a positive change of attitudes towards science, especially with regard to attitudes towards citizen science endeavors and science news. In line with Rutjens et al. (2022), this study also found that the participants' increase in scientific literacy plays a role in this change in attitudes (Price and Lee 2013, 773).

In addition, science skepticism can also be countered by citizen science through psychological effects.

3.4.2 Psychological effects

A psychological effect resulting from citizen science is experiencing a feeling of ownership that can help reduce science skepticism. The reasons for this sees Acar

(2023) in the psychological effects of contributing to an endeavor or outcome. First, if people can participate in the creation of products or outcomes, they have a positive bias towards it. Therefore, self-created products have a higher value (Norton et al. 2012) as persons are experiencing feelings of competence during creation as well as a greater feeling of psychological ownership. This so-called IKEA effect (Norton et al. 2012) might therefore also be seen in citizen science since even small contributions to an endeavor cause this effect and result in more confidence in science and thus less science skepticism (Acar 2023, 2).

Second, if participants experience psychological ownership for a citizen science project, they may also engage in science advocacy (Acar 2023, 2). Participants may share information about a citizen science project on a positive note with their families and communities (Johnson et al. 2014). Therefore, participants in citizen science projects experiencing psychological ownership can engage in science communication and help counter misinformation related to science (Acar 2023, 2).

Third, non-participants might experience psychological effects of citizen science as well. By observing others, and following their empowerment, non-participants might also experience feelings of empowerment, acceptance of and identification with science as well as more trust in science. Therefore, increasing the visibility of citizen science endeavors can help to harness these psychological consequences among the general public (Acar 2023, 3).

This shows that participation can have an effect. Therefore, communication is crucial in citizen science projects. The communication by citizen science project researchers or communicators may thus also affect science skepticism. However, Acar (2023, 3) sees the main responsibility for the communication against science skepticism among policymakers and research organizations since they strongly depend on the public's trust in science.

3.4.3 The role of participation

Apart from these psychological effects, participation also has other implications. "Science is debate. And […] critical members of the public can partake in this debate" (Lewandowsky et al. 2016, 543). Moreover, participants can contribute their knowledge, experience and concerns to academic research. "Given that scientific issues can have far-reaching political, technological, or environmental consequences, greater involvement of the public can only be welcome and may lead to better policy outcome" (Lewandowsky et al. 2016, 540).

Citizen science can change the role of citizens from passive consumers of scientific results and their role as audience to active participants in the research process. This way, they may help to legitimize science in society (Hecker and Taddicken 2022) or increase

trust between science and the public (Strasser et al. 2019). However, there is no clear evidence for these statements so far (Peters et al. 2023, 14).

3.4.4 Importance of communication

There are various ways of countering science skepticism by means of (science) communication. Regardless of the step in which members of the public are engaged in academic research, i.e., topic definition, data collection, data analysis etc., communication is always key (Hecker 2022). Apart from communication being crucial for participant recruitment and retention as well as the quality of the citizen science project, communication is also key to create the aforementioned feeling of ownership and to establish a feeling of belonging and community. Furthermore, communication can also help to create a feeling of contributing to a greater good and to enhance scientific literacy.

A negative attitude towards science is not necessarily related to a lack of knowledge about science. Here, the deficit model in communication plays a role because it can become a self-fulfilling prophecy and even further increase the distrust between academics and the public. If researchers consider members of the public as deficient, who cannot be trusted, it creates mistrust on both sides, academia and society (Bauer 2009, 225). If there is no trust or confidence on both sides and there are false conceptions about each other, communication is misguided. This way, the public might be even further alienated from academics (Bauer 2009, 225). Therefore, this is a crucial aspect when assessing the relationship between science and society and investigating science skepticism.

Since science skepticism is not a homogeneous phenomenon, science should open up communication with other members of society characterized by dialog. Since science skepticism may be only related to a certain topic, communication plays an important role (Starkbaum et al. 2023, 6). However, to help counter science skepticism (and not worsening the situation), the stakeholders engaging in communication and public discourse require skills and training, including the ability to reflect on their own practices and interests. Additionally, they should be transparent in communication (Starkbaum et al. 2023, 6). Despite all its promises and the added value that citizen science can have for the participants, citizen science requires trained researchers who are well-versed in tackling the complexity of a citizen science project and the variety of issues it entails. Thus, well-trained researchers who are treating participants with respect, engage in mutual dialogue and are willing to adapt are the foundation for countering science skepticism by means of citizen science.

Communication in citizen science is not limited to the traditional dissemination of scientific findings in academic journals and during academic conferences. It is also characterized by the outreach to the public, by media and influencing stakeholders and

policymakers as well as creating change through research. Thus, impact might be crucial. In its most comprehensive form, citizen science might involve members of the public also in decision-making regarding the research design, the topics to be addressed, the research question to be answered or the method and means of publication to be selected, which again highlights the importance of the psychological effects of ownership and participation.

Science communication which targets negative attitudes towards science can have different objectives according to Peters et al. (2023): Science communication might work along two lines: increasing and strengthening trust and reducing negative effects of expressions of science skepticism (especially in the form of online communication). On the one hand, trust can be strengthened by communicating openly and clearly about the scientific process and uncertainties, by being transparent and engaging in open science. In addition, trust can be earned by public engagement in the scientific process, especially through citizen science. On the other hand, negative effects can be reduced by increasing the recipient's resilience towards misinformation through education, by prebunking, i.e. the process of debunking misinformation or sources before they strike, and addressing common misinterpretations and misconceptions regarding a topic already in the beginning. Furthermore, negative effects can be minimized by reacting to misinformation or disinformation through providing evidence-based facts or by supporting researchers being affected by public attacks.

However, to be effective in countering science skepticism, science communication measures must be targeted. Moreover, communicators must be aware of the fact that measures suitable for addressing one attitude can be counterproductive for another attitude (Peters et al. 2023, 17).

3.4.5 Value and appreciation

The way how researchers or communicators communicate in citizen science projects can have an effect on the participants' attitude towards science. Therefore, it "is also important to signal that the public's input is genuinely valued; otherwise, these initiatives might exacerbate skepticism rather than mitigate it" (Acar 2023, 3).

Within a citizen science project, communication can create a sense of belonging and a feeling of being part of a community with shared values and visions. Communication can also create ownership and help change attitudes. In addition, the appreciation of the participants in various forms can have implications for science skepticism. Appreciation might range from social rewards, such as co-authorship in academic publications or rankings to increased social status in the project, for example by being a mentor or senior participant (Dunn and Hedges 2013, 153). Furthermore, citizen science projects should be appealing to as a broad range of people as possible. This can help to engage persons

who are genuinely not interested in science. Projects can increase their appeal through gamification, monetary incentives or, as mentioned before, recognition (Acar 2023, 3).

3.4.6 Benefits

A crucial aspect for the success of a citizen science project, from the participants' point of view, is the benefits they see in the project. These benefits might be direct benefits, such as hedonism, indulging in a hobby, being part of a community or (perceived) meaningfulness and (social) relevance as well as a means for improving their personal environment. The latter is often characterized by community science projects and usually concerns questions related to environmental justice and social justice. Here, research has shown that children participating in eco citizen science projects benefit in terms of their development and increased environmental stewardship (Makuch and Aczel 2020, 219).

In the initial phase of participation, people are strongly driven by personal pursuits. These are the reasons why people are volunteering in the first place. These personal pursuits include personal interests, self-promotion, social responsibility, and self-efficacy. These refer to engaging in their hobby, gaining personal reputation or social advancement, and contributing to scientific knowledge gain as well as to nature conservation or pride for their local environment (Rotman et al. 2014, 230). During the course of participation in a citizen science project, these motivations tend to change. Over the course of the project, the trust in the project, including the researchers, the data quality, and the practices as well as aspects related to communication play an increasingly important role. Here, clear communication, a common goal and contributions that are valued by the researchers can be essential (Rotman et al. 2014, 231–232).

At a later stage in the project, participants might have already invested quite an amount of time and effort. For example, after participating in training, reading materials, and contributing to the project in different ways, participants require acknowledgement and appreciation. These can range from a personal note to the participants, acknowledgements in academic publications, access to knowledge and resources or empowerment, activism and influencing policies at different levels, from the local to the national or supranational levels (Rotman et al. 2014, 231–232). Therefore, long-term participation is characterized by a combination of personal and collaborative aspects. Addressing these different motivations becomes even more difficult when combined with the wide range of perceived and expected benefits of participants.

Citizen science can become a means for countering science skepticism if it can provide added value for participants. This added value can be the benefits, the relevance, the meaningfulness, and the impact they perceive following participation in a citizen science endeavor. However, since this perceived benefit differs between participants, might be

highly individualized and depends solely on the individual participant's assessment, it is hard for citizen science projects to meet everyone's expectations and needs. Nevertheless, clear communication throughout the project, feedback loops with and evaluation by the researchers and the participants in citizen science projects can help to identify, voice, and manage these expectations. Expectation management in citizen science can support researchers to counter disappointment and thus skepticism.

To sum up, in addition to the role of participation and communication, citizen science can contribute to lowering science skepticism. Here, it is crucial that participants see a (direct) effect on their personal lives, including psychological effects of ownership or belonging. Even small or very personal benefits from participating in academic research can make a difference.

The limitations of this study are the small number of articles reviewed and the focus on only one database. While some 'synonyms' for citizen science were used as keywords, synonyms for science skepticism would lead to more comprehensive results. Nevertheless, this study opens up questions for future research since it hints at the positive effect of citizen science on countering science skepticism. However, science skepticism is a complex phenomenon that might not be solvable by means of citizen science (alone).

4 Conclusion

Citizen science holds many promises, such as increasing public understanding of science, acquisition of subject-specific knowledge and scientific literacy among participants in citizen science projects. It may also help to change the relationship between science and society for the better. In this regard, citizen science can be an instrument to counter science skepticism throughout European societies. Despite the limitations of citizen science with regard to being inclusive, managing expectations and providing added value for the participants (or society), citizen science can change attitudes and draw on (psychological) effects of ownership, belonging, appreciation and empowerment. Since (science) communication is crucial to counter science skepticism, not only citizen science projects but any science-related stakeholder, such as researchers, research organizations or policymakers can contribute to a positive change of attitudes towards science.

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